Input Productivity in Agriculture on the North Coast of Colombia

By

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KEY TO ABBREVIATIONS

ASOCESAR--Asociación de Algodoneros del Cesar.

Caja Agraria (or Caja)--Caja de Crédito Agrario, Industrial y Minero.

CORAL--Corporación de Algodoneros del Litoral.

FEDEALGODON--Federación Nacional de Algodoneros.

FEDEARROZ--Federación Nacional de Arroceros.

FFA--Fondo Financiero Agrario.

ICA--Instituto Colombiano Agropecuario.

IDEMA--Instituto Nacional del Mercadeo.

IFA--Instituto de Fomento Algodonero.

INCORA--Instituto Colombiano de Reforma Agraria.

All monetary figures are given in Colombian pesos; one peso = approximately U.S. $0.054 at the time of this study (1970-71).

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INPUT PRODUCTIVITY IN AGRICULTURE
ON THE NORTH COAST OF COLOMBIA

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The objectives of this study were to estimate input productivities, efficiency of input allocations, and to relate the supply of capital to input demand.

Regression analysis and linear programming were used to estimate the marginal productivities of three classes of inputs--machinery, labor, and non-traditional cash inputs (including fertilizer, pesticide, herbicide, and improved seed)--in the cotton zone on the North Coast of Colombia. Data obtained in farm interviews were used to derive production functions for cotton, rice, sesame, and sorghum. A survey was made of the institutional credit system in the area with respect to the amount of credit available, lending terms, and interest rates. Using supply and demand functions for capital funds, a range was estimated for each crop within which financing crop production through borrowing would be economical.

Results of the regression analysis show that the input levels in the study zone were not optimal. In Colombian pesos, the MVPs for machinery, labor, and cash inputs at the mean levels of use were: for cotton, -37.7, 26.3, and -0.07; for rice, 124.5, -261.6, and -0.77; for sesame, -140.4, 10.6, and 117.1; and for sorghum, -100.8, and

41.3, respectively. Data were not available for cash inputs for sorghum. Thus for cotton, machinery was used excessively, additional labor inputs would have been profitable, and for the aggregate of non-traditional cash inputs the mean level was very near the optimum. For rice, machinery was under-used while the labor input exceeded the optimum level and non-traditional cash inputs were very near the optimum level. For sesame, machinery was used excessively, while the inputs of labor were below the optimum level, and non-traditional cash inputs were near optimum level. In sorghum production, machinery was used excessively, while the labor input was below the optimum level.

Input prices in Colombian pesos were: machinery, 44.00 per hour; labor, 3.75 per hour; and cash inputs, 1.08 per peso.

Optimum cropping systems were developed for four different income objectives, with risk taken into account.

Results of this study indicate that there are sufficient credit resources in the area to provide financing for a high percentage of production costs. The major problem with respect to credit is its inaccessability to some types of farmers. However, through the facilities of government initiated programs and the crop associations, nearly all farmers can borrow at least 50 percent of their production costs.

CHAPTER I

INTRODUCTION

The Problem

The allocation of capital within the agricultural sector[1] of a developing nation is, or should be, of primary concern to those who are formulating or implementing development policy. The critical nature of the use of capital is in large part created by its shortage as an input in the development process, and by the widespread demand and need for capital inputs to escape from what is now commonly called "traditional" agriculture (2, p. 18).

A scarcity of capital may present barriers at various levels of potential investment (37, pp. 83-6). At one level is the shortage of investment capability on the part of a large portion of the agricultural entrepreneurs. This shortage is aggravated by the reluctance to commit substantial portions of available capital to agricultural activities (17, p. 2; 11, p. 42; 22, p. 999; 34, p. 7) and the inefficient use of resources employed in agriculture, which reduces the "effective" capital in this sector. That is, while the quantity of capital invested in agriculture may be at one level, its productive effect may be at a lower level which creates an apparent shortage as an excessive amount of capital inputs is required to achieve a given level of output.

[1]There is also the question of intersectoral allocation of capital which must be considered by planners. However, this subject is not considered here.

On the part of government there is often a lack of physical capital resources that are necessary for the implementation of programs for agricultural development. Public investment in or support of various agricultural activities must be limited and priorities must be established to guide the use of available funds. A second problem arises in the financing of "modernization" due to the demand for foreign-produced inputs. The nearly universal lack of adequate foreign exchange in developing countries restricts the importation of capital inputs. Similarly, borrowing on a governmental level to support agricultural programs can be limited by the foreign exchange imbalance unless provisions are made for repayment in local currency or export products.

Finally, foreign private investment as a source of capital to meet investment needs in agriculture is, except for a few specialized export crops, an unpromising basis upon which to build a program of agricultural development. The foreign private investor is reluctant to assume the risks and uncertainties associated with production for the internal market which is often small, complex, and poorly organized (31, pp. 24, 82-9). In addition, the growing negative attitudes toward private investment which are encountered in many developing countries are another obstacle to the entrance of capital from foreign sources. Thus, the expansion of the supply of private investment to fill the needs of the domestic agricultural sector is highly unlikely (9, pp. 94-8).

In light of the foregoing discussion it can be inferred that there is a strong possibility that the capital resources available for agricultural development will be inadequate to support the desired program

of modernization. Further, it is probable that the resources on the firm level are generally insufficient to permit the luxury of inefficient use. That is, if the farmer has as one of his goals the realization of a reasonably high return to inputs, he must seek the activities which use his capital most efficiently. Thus, at both the government and at the firm levels there is a need for indicators of the relative productivity of capital among its alternative uses. Without such indicators (which is generally the existing condition) government programs of technical assistance, credit, and infrastructural investment are formulated and administered with little knowledge of the amount of capital available and its potential and actual productivity. Allocations are made on the assumption of a capital shortage in all activities and more or less equal returns among alternative investments. On the firm level apparent returns to investment govern the choice of enterprises, and actual productivity of capital and other inputs is largely unknown.

In part, due to a lack of data obtained from or describing on-farm conditions, planners and policy-makers in the agricultural sector must draw upon estimates based upon information either from external sources or experimental results. The inadequacy of this type of information has been noted by various authors (23; 36, p. 254). Heady has been concerned with the problem of explaining the difference between theoretical optima and actual outputs in the United States, a concern which is appropriate in many developing countries today. Referring to the U.S. agricultural situation following World War II Heady argued that:

> More is known about the optimum than about the extent and cause of the gap between the existing and the optimum. Theory provides tools which

> explain the optimum scale of operations and combination of resources in general. ...obviously, there is some important and sound reasoning in the minds of farmers for not attaining this optimum even though it be what the most profitable farm is doing. ...numerous forces condition the use of resources on farms and explain this gap. ...production economics research should probe further in exploring this gap as reflected on individual farms. Only then will attempts to bring about the most efficient use of farm resources be entirely realistic. Individual farmers can be better advised. But as important is the fact that a base will be laid for altering customs, institutions and programs which condition the efficiency of farm production (13, pp. 224-5).

The last-mentioned benefit of determining the actual on-farm productivities of inputs, that of serving as a guide for large scale changes, is primarily related to government action which would be based upon information gathered at the farm level. With the governments of the developing countries playing key roles in the development process, it is imperative that they be supplied with this type of realistic data (33, p. 133; 36, p. 254).

Objectives

The major objective of this study is to calculate the productivity of the agricultural inputs used in the study area--an area located at the eastern end of the cotton region that stretches across most of the Northern Coastal Zone of Colombia. Special interest is given to the productivity of the non-traditional inputs and the variable capital invested in selected enterprises. In light of the results of the productivity determinations three further questions are considered:

1. The adequacy and allocation of credit supply.
2. The efficiency of the input mix and levels for cotton, rice, sesame and sorghum.

3. The allocation of resources among alternative crops.

Based upon the results of the studies of the above questions, recommendations are made with respect to the following items:

1. Credit policy.
2. Factor levels for specific crop production.
3. Farm organization to achieve selected income goals, namely: (a) maximizing income, (b) maximizing return to owned capital, (c) maximizing the probability of realizing a selected income level, and (d) minimizing losses.

Plan of Presentation

The thesis is presented in seven chapters. In Chapter II a general discussion of the approaches and analytical techniques is presented. In addition, the types of risk and uncertainty encountered in the agriculture found in the study area are defined, classified, and discussed. Methodology is established that is used later to indicate the risk revealed by investigation and discussed with relation to the final crop combination recommendations.

Chapter III provides a brief overview of the agriculture in the study area, and includes a discussion of the present situation with respect to inputs and crops, current and potential problems, and the relevant agricultural programs in operation or proposed. In the second part of Chapter III data collection procedures and the specific problems presented by the conditions in the area are discussed.

Capital availability is the subject of Chapter IV, in which a discussion of the institutional sources of credit is given. The conditions related to the acquisition of capital from these sources

are examined, and the existing institutional arrangements with respect to capital supply and the effects of these arrangements on capital use are discussed.

The analyses of data collected in the study area are presented in Chapter V. The results of the regression, production function, and linear programming analyses are given and discussed. The central theme of the chapter is concerned with the comparison of capital productivity among inputs for each product and among products for each input. The value of the results of the normative linear programming analysis is discussed in light of existing conditions and future potential.

In Chapter VI, the results of the supply and demand for credit and capital are synthesized. Finally, in Chapter VII, the results are summarized, and the major conclusions and recommendations indicated by the study are presented.

CHAPTER II

METHODOLOGY

Regression, Production Functions, and Linear Programming

Positive vs. Normative Analysis

> By normative we refer to the course of action which ought to be taken...when (a) the end or objective takes a particular form and (b) the conditions and restraints....are of a particular form....the term positive is used...to describe analyses which explain phenomena as they exist...(14, pp. 8-9).

Production function (via regression) analysis is of the positive category. Once the coefficients have been estimated by means of regression analysis, the calculated function describes how the changes in inputs affect output within the existing organization of production. That is, the production function equation defines the relationships between input and output under the particular system of production in question.

Similarly, the predictive aspect of the production function is positive in nature. Using the production function one can predict the effect on output of changes in the independent variables. Given the specified functional relationship one can estimate what would or will be the results if certain actions are taken. Yet, although one is dealing with future results, the answers obtained are based upon the assumption that the existing firm structure will not be changed. The accuracy of the predictions depends upon the accuracy of the model

(production function) and the accuracy and adequacy of the observations used in the estimates of the coefficients.

Linear programming is a normative tool of analysis. Using observed or derived input-output coefficients and prices, the solution obtained is that which best satisfies the objectives and constraints of a contrived problem. The solution indicates the action which should be taken to achieve a stated goal, and does not necessarily describe the practices which are presently being followed in the study area. The output indicated by linear programming is that which represents the optimal utilization of the resources available, combined according to the relationships specified by the coefficients. Thus, linear programming is used to indicate a reorganization of production and resource use in order to realize the given objective. Numerous factors may cause this normative model to differ from actual conditions, and the value of it lies in its use as a guide toward efficiently employing resources in achieving specified ends.

A Note of Comparison

A basic difference between regression analysis and linear programming was discussed in the preceding section comparing positive and normative analysis. Briefly, it should be remembered that production function analysis, using coefficients derived by regression analysis, can be used to solve the maximization (minimization) problem under existing conditions, that is, under the existing organization of production. The solution given is in the context of, and in accordance with, the actual structure of the production process. The use of linear programming in the maximization or minimization problem permits

one to introduce coefficients derived from various sources, which gives a greater degree of flexibility to this phase of the analysis.

In linear programming the input-output coefficients are inputs into the model. That is to say, they are postulated by the investigator according to the purposes of the study. This enables one to choose among several sources of data for the programming coefficients (e.g., those derived by regression analysis of experimental and actual farm data, those provided by technicians, or those derived from any combination of these sources), and permits programming to deal with techniques, inputs, and products that may differ from actual farm experience--an important advantage over production function analysis when dealing with questions of change. In production function and regression analysis, however, these coefficients are determined by the data. They describe the input-output relationships in the study population. This aspect of the two methods of analysis is closely related to their positive and normative characteristics.

Applications in This Study

Both production function and linear programming procedures are appropriate for use in this study. Because of the lack of information with respect to present production methods, regression analysis is used to determine input-output relationships under existing farming conditions. Further, the production functions derived are used to evaluate the productivities of the inputs and to estimate the effects of changes in input levels. Based on the results of regression analysis, production functions are used to make comparisons of the productivity of different inputs with respect to one crop and among several alternative crops.

Linear programming is applicable in the study as a tool for determining optimum crop combinations and for determining the value of limiting inputs. This method of analysis indicates which crops and how much of each crop should be produced to achieve the income goals of the farmer. Some of the inputs into the model are modifications of the present levels of inputs or of the yields currently obtained. These modifications are especially useful in the cases of sesame and sorghum for which experience in the study area is quite limited and the data available are from a very small sample. Data from other similar agricultural areas are used to modify the data from the study zone.

Evaluating Input Contribution

The basic measure of the contribution of an input to the production process in production function analysis is its marginal physical productivity (MPP). The partial derivative of the production function with respect to input X_i (equation 2-1) is the MPP of this input.

$$\frac{\partial Y}{\partial X_i} = MPP_i \qquad (2\text{-}1)$$

Based on equation (2-1), the monetary value of the change can be easily calculated. This value, the marginal value product (MVP), is the marginal physical product multiplied by the price of the output (P_y), and indicates the change in income brought about by the change in the use of input X_i. Profit (net income) can be maximized by equating the MVP_{xi} to the input price (P_{xi}) and this point is referred to as the optimal level of X_i. The optimal level of each input can be obtained by the simultaneous solution of the set of equations of the

MVPs for each input. Thus the simultaneous solution of equation (2-2) will yield the optimal levels of the X_i through X_n inputs.

$$
\begin{aligned}
MVP_{xi} &= P_{xi} \\
MVP_{x2} &= P_{x2} \\
&\vdots \\
MVP_{xn} &= P_{xn}
\end{aligned}
\qquad (2\text{-}2)
$$

Linear programming does not allow for the estimation of the marginal value of an input while all other inputs are held constant. Rather, the shadow prices which are given by the program indicate the increase in profit (when the objective function is a profit function) if the supply of the scarce resource is increased by one unit. A scarce resource is one for which the supply has been completely exhausted in the program solution. The shadow price represents the monetary value of the increase in output using the additional unit of the scarce input in combination with the corresponding quantities of the other inputs.

Risk and Uncertainty

The distinction between risk and uncertainty is that the former can be quantified in terms of probabilities. The probabilities of outcomes or occurrences in a risk situation are measurable; whereas, in the case of uncertainty they cannot be meaningfully measured (20, pp. 19-21, 197-233). When outcomes can be expressed in terms of probabilities, decision makers then may be able to compensate or allow for risk.

Relevance of Risk and Uncertainty

The elements of risk and uncertainty in agriculture have a much greater effect on decision-making in the developing, and poorer, countries than in the advanced countries where various means of reducing or coping with risk and uncertainty have been developed. There are several circumstances which account for this situation:

1. Many of the farmers in developing countries cannot afford, or withstand, a production failure or a financial loss for even one production period, thus they avoid entering into activities with which they have little experience or personal knowledge (35, p. 167; 4, p. 405).
2. The types of changes which yield the greatest increases in return are often characterized by a high degree of variability in results, and require a relatively large increase in expenses (12, p. 445). These changes often require an increase in cash capital inputs rather than in land or labor.
3. There is much less opportunity to shift risk in developing countries (e.g., through insurance or price support programs). Also the chances of being able to diminish or eliminate risk and uncertainty are lower in developing countries where inputs which alter the agricultural environment--such as irrigation, fertilizer, and pesticides--are not as readily available.
4. The level of knowledge and control and the extent of information services regarding agricultural production

are lower in the developing countries partly due to the characteristically poor communication network for transmitting information concerning new techniques, research findings, weather and market conditions (10, pp. 251-3).

Sources of Risk and Uncertainty

There are several possible causes of "loss" as well as various resources and outcomes which can be gambled in a risky situation. It appears that three distinct aspects in the study of risk and uncertainty will be useful in clarifying and organizing the subject.

First is the identification of the sources. For present purposes this is done by discussing three sources: inputs, prices, and yields. These sources are by no means exhaustive, nor mutally exclusive. However, since a principal objective of this study is to arrive at conclusions which can be implemented into actual farm decision-making practices, these three source areas are chosen on the basis of their relative importance, identifiability, and measurability.

Following the identification of the risk elements one is faced with the task of their measurement. This necessarily must be done in part on a subjective basis, firstly due to a lack of available data, and secondly because it is the perception of risk by the farmer which is usually the important element in his decision-making. More objective measures can also be introduced, but they must be used in a manner which is consistent with the realities of the decision-making process.

Finally, based on the quantifications of the risk elements, a risk model can be constructed. Risk models may be either of a predictive type or a prescriptive type. For the purposes of this study, the

prescriptive model is formulated as it appears that the present system of exploitation in the study area would benefit from changes that may be indicated by such a model.

Input availability, appropriateness, and quality

Especially in the agriculture of developing countries risk and uncertainty surrounding input use, and, in particular, "non-traditional" input use, are of primary importance (34, pp. 145-6; 25, Chapter 13). The decision to adopt new inputs (and in the sense of input into the whole agricultural production process this includes new plants, new varieties, different practices, etc.) must be made in view of the risks associated with them (26, p. 47). Three areas of risk or uncertainty surrounding the employment of modern inputs in developing countries are the availability, appropriateness, and quality of these inputs.

The availability of inputs in agriculture is critical with respect to the physical quantities in which they are made available as well as the timeliness with which they are delivered (27, p. 32). The subsequent increases in the uncertainty and risk which is associated with a greater use of modern inputs are often ignored by advocates of modernization (12, pp. 44-5). The problem of availability is difficult to pinpoint in that deficiencies of supply and timeliness manifest themselves in much the same way, yet the solution to each is quite different. Both conditions are evidenced by a lack of inputs at a critical time in the cropping season. However, the pure supply shortage is due to production or importation factors, and the problem of timeliness of delivery is a communication and transportation problem. The question of the measurement of availability is likewise confounded.

Unless a separate study is made on input supply, indications of the adequacy of supply must be obtained from subjective sources. These sources are principally opinions and estimates of suppliers and users of the inputs. In the present study no attempt is made to quantify the availability of inputs. However, the problem was encountered in the study region.

The problem of availability in the study zone was observed particularly with respect to insecticides and cottonseed. For insecticides the problem was one of timeliness of local delivery and application, whereas for cottonseed there were delays in importation and regional distribution. Locally, defined as the Cesar-Guajira major cotton areas, specific insecticides were frequently difficult to obtain on short notice and subsequently substitutes were employed. The problem of shortages is amplified by the poor network of communications which decreases the probability of locating the needed insecticide in time for it to be used effectively.

There is often difficulty in contracting for spraying when needed, when this need arises suddenly. This difficulty is partly due to the tight schedules of the fumigation companies during the growing season, and partly a result of pest problems occurring simultaneously on several farms in the stricken area.

All distribution of improved cottonseed is coordinated and controlled by the Instituto Colombiano Agropecuario (ICA). In recent years serious shortages have been experienced due to problems of importation or inadequate initial purchases from foreign dealers (principally in the United States). The importation difficulties have generally been associated with clearing the seed through customs, and

the effects are spread throughout the North coast cotton region. Distribution problems are also encountered for domestically produced seed. Transportation between storage facilities and local seed outlets is frequently inadequate to meet the demands during the planting season. The short planting season, with the optimal period lying between 20 July and 20 August, increases the need for an adequate distribution system, and world competition necessitates that Colombia continue to use imported varieties of cotton in order to produce a fiber consistent with demand.

The second aspect of input uncertainty relates to the appropriateness of modern inputs in developing countries and has been under discussion for some time. By and large, this discussion has concerned itself with the problems of transferring modern technology to the developing agricultural sectors (16; 38; 24). Due to several factors--such as climate, light, and soils--often it has been found that recommended practices and products have not given expected results, even to the point where losses have been incurred by farmers who adopted the recommendations. Further--and this is usually more a matter of degree of success rather than a success or failure situation--recommendations from the research organizations in the developing countries themselves have often not yielded the increases in production indicated by experimental results (8; 23). There are often very large differences between the experimental yields and those realized under actual farming conditions. A good indication of the "productivity gap" in Colombia has been given by Lopera and Hildebrand (23); a gap which should emphasize the large degree of uncertainty surrounding even the adoption of inputs which have been developed and tested within the country in which they are to be used.

Quantitative expression of the use, and effects of using, inappropriate inputs would be a very difficult task. Examples, however, were seen in the study area, especially with regard to recommended seed varieties of sorghum and sesame. The sorghum variety which was recommended by ICA for the area was ICA-PAL which was developed by ICA at their experiment station in Palmira in the Cauca Valley. This variety did not prove to be well suited to the Cesar-Guajira zone. The lower one-quarter to one-third of the head of the plant remained surrounded by vegetation, and during the final months of growth and ripening, rain water trapped in this bowl around the grain, causing it to rot, resulting in a loss of 25 to 33 percent of the crop.

In the case of sesame several of the recommended varieties were found to be highly susceptible to a disease which was difficult or impossible to control. Until new resistant varieties were introduced the chances of yield losses due to diseases were extremely high.

The final aspect of input risk and uncertainty to be discussed is with respect to the quality of inputs. This question arises partly from a lack of initial control over production and importation, and partly from problems occurring in distribution and application. The implication of low quality inputs are obvious and need not be discussed. Clearly if the users of the inputs cannot have confidence in the product being used, the uncertainty of the outcome resulting from its use is increased. By sampling and testing the inputs in the various stages of the production-distribution process this phase of input uncertainty can be measured and presented in a quantitative expression of risk.

The ability to detect and control quality deficiencies decreases as the input approaches the stage of actual application (18, pp. 17-20).

At the point of production or importation control can be exercised rather effectively as there are only a few sources of the inputs. However at subsequent points in the distribution system the problem of quality supervision becomes more critical and more difficult. As distributors at the various "break-down" points become responsible for mixing and packaging, the opportunity for contamination, dilution, and misrepresentation greatly increases. Thus, vigilance is necessary during all phases of production and distribution of inputs to the farmer, and inadequate control at any point is sufficient to prevent the buyer from receiving the expected quality of the input.

Results of the analyses of samples taken by ICA in 1970 are given in Table 1. These results are not encouraging when one considers that fertilizers and pesticides are essential to the success of the major segment of the agricultural sector in the study zone. The high proportion of poor quality ratings for fertilizer samples throws much doubt on the real effects to be expected from this input. The percentage of substandard pesticides was not as high as was the percentage of fertilizer samples. However, it should be noted that nearly one-half of the pesticide samples taken had not been tested. It becomes rather obvious that the quality of inputs could be, and perhaps is already, a serious problem for the farmer.

Prices of products and inputs

In a market where there is very limited guarantee of prices, subsidies, or output control, price fluctuation is a major cause of uncertainty with respect to farm income (26, pp. 52-6). Price uncertainty manifests itself in input prices as well as in product prices.[2]

[2]See Heady (12, pp. 460-4) for tables on price variability in the United States.

Table 1. Results of ICA's Input Quality Tests in Colombia

Type of Result	Fertilizer		Pesticides	
	Number	Percent	Number	Percent
Correct[a]	251	48.8	290	43.0
Incorrect[b]	200	38.9	81	12.0
Pending or Unacceptable[c]	63	12.3	300	45.0
Total	514	100.0	674	100.0

[a]Correct denotes that sample contained ±3% of the indicated level of ingredient(s).

[b]Incorrect denotes that the amounts or concentrations of the relevant ingredients were not within the acceptable range established by ICA.

[c]Sample was termed unacceptable for various reasons among which were that the material was not that which was claimed to be sampled or improper packaging rendered the sample untestable.

Product price.--Large price variations occur among farms in a geographic zone during the same semester, and from one cropping period to another on any given farm.[3] At the time inputs are purchased and allocated to production, the farmer is likely to have very little basis for estimating what the price of the output will be. Due to the general ignorance of alternative market opportunities, relatively small scale of production, and high transport costs, the local market or buyers of a particular crop are the only outlets considered by most producers.

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[3]In the study sample which includes prices over a two-crop period, the difference between the high and low reported prices was great. This difference, expressed as a ratio of higher to lower price was: cotton 1.46, rice 1.54, sesame 1.58, and sorghum 1.44.

Thus, at harvest time farmers face monopsonistic, or at best oligopsonistic, situations. Prices depend greatly upon the particular conditions of the local market; thus, the stage is set for potentially wide price variations. To ameliorate the effects of large price fluctuations conditioned by variations in production, and most importantly the low prices associated with "good" years, one cannot turn to the various methods usually employed in the developed countries. Insurance and price supports are rare. Adequate storage is often not available and the farmers have an immediate need for money to begin preparations for the new cropping period and to repay the loans from the previous one. Loan periods usually correspond to the production-marketing time of the particular crop, with severe penalties for deliquency in repayment.

In any particular selling period one encounters wide price variations from one market to another. The variations usually are not as great as annual variations within a given region. It is very difficult to predict what the prices in a distant market may be if one can only base his expectations on local conditions. With the inadequate communications found among regions, the producers must frequently resort to guesswork concerning outside market conditions. When selling to buyers who function on a national scale (a good example in Colombia is PURINA in the grain market which pays nearly 35 percent more for sorghum than local Cesar buyers) higher prices are offset by uncertain transportation costs associated with shipping relatively long distances and in small quantity. The earnings thus associated with the crops are often not sufficient to compensate for the risks involved in producing them, especially when levels of income are quite low, and farmers can hardly afford a loss in any year.

A third factor which creates an element of price uncertainty is the low degree of quality control of output and the relative indifference to quality by the buyers. Grading is often done after several farmers' crops have been combined, resulting in an averaging of the overall quality, which is an obvious disadvantage to the producer of high grade output. Thus, even if one were to control fairly carefully the quality of his own production, there is no guarantee that it will be judged consistently by buyers from one period to the next.[4] A companion problem in this quality-price relationship is the degree of quality control in production, and will be discussed briefly in the section on yield uncertainty.

Input price.--Prices of inputs are generally more stable than product prices. Certainly one does not usually face the possibility of fluctuations in both directions. At the time of purchase and use the prices of inputs are known. However, it is often the case in the developing countries that the prices of modern inputs are constantly increasing, a condition which would be most critical to growers of long-term crops, but also important to those farmers wishing to plan rotation patterns and crop substitutions.

In the initial stages of modernizing the agricultural sector, the source of inputs is usually importation from foreign manufacturers. The price is thus higher than in the country of origin due to extra transport and marketing costs. In addition, these agricultural inputs must compete with other classes of imports for limited foreign exchange

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[4]This practice is especially prevalent in the case of cotton. There is little premium for high grade fiber in that the cotton from different farms is combined before grade and price determinations are made.

and are subjected to tariffs of varying magnitudes depending upon the priority given to them. As the quantity of total imports increases, the general level of tariffs may also be increased in an effort to curb the real and potential trade imbalance. Unless specifically excluded, the rise in tariffs would be evidenced in the price of agricultural inputs.

In the initial stages of development, domestic production of modern inputs is also associated with high prices (unless perhaps the industry is subsidized). The developing countries are often forced to import raw materials, thus facing a situation similar to the one described above. In addition, these new industries do not enjoy the economies of scale which may be present in the developed countries which are producing for a large market, nor can they benefit from the technical advancement that industry in general exhibits in the advanced countries.

A further reason for rising prices over time is that production and importation do not keep pace with demand. Due to the bottlenecks encountered in the limited capacity of the sources of inputs, demand is frequently seen to increase faster than supply. An eventual stabilization or even decrease in price must wait until the industries have achieved the economies of scale associated with adequate market size and complementary industrial development.

Yield uncertainty

Weather conditions are most likely to be the major cause of yield variability.[5] Although instances of extreme weather conditions either

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[5] In the study sample which includes yields over a three-crop period,

destroying or aiding in the realization of disasterous or bounteous harvests are observed, more usually the variation is less drastic, and the resulting effect on yield is less dramatic. The sensitivity to weather differs among crops, and,therefore, must be an important consideration in selecting factor and crop combinations for areas which are subject to a wide range of weather characteristics.

Yield can be greatly affected by diseases and pests. The increasing control possibilities have lessened the uncertainty surrounding this source of variability. However, in countries in which the agricultural sector is in the modernization process, the decline in dangers associated with plague incidence is a slow process and often new and unexpected outbreaks are experienced. The adoption of new crops and the introduction of crops into new regions is often followed by rapid increases in pest and disease incidence in spite of the existence of chemical and natural means of control.

The final aspect of yield uncertainty that will be mentioned is that related to technological change. A crucial point often overlooked by developers is the extent of the uncertainty of the effects of the introduction of new technology. The uncertainty inherent in any major change in the existing system of agriculture must be a key factor in the decisions concerning innovative practices.

The preceding points have been directed toward yield variability with respect to quantity of output. Weather, pests and disease damage

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the difference between the high and low reported yields was great. This difference expressed as a ratio of higher to lower yields was: cotton 3.33, rice 8.40, sesame 3.18, and sorghum 5.33. Farms with zero yields were reported for each crop; however, these zero values were not used for the present comparison.

can greatly affect the quality of the product as well. Cotton is especially susceptible to quality changes. One study showed a significant correlation between rainfall (days of rain and measurable rainfall) and quality of cotton produced. A positive correlation was observed between rainy conditions and amount of ginning waste, and negative correlations occurred between rainy conditions and cotton grade as well as staple length (21, pp. 20-22). The grain crops are also affected adversely by excessive moisture during the harvest period. Excessive moisture content of the grain results in a lower grade and price (with a likelihood of being rejected by some buyers).

The effects of pests and disease on quality of output are perhaps even more obvious. Partly destroyed crops, crops infested with insects and other pests, and disease-damaged products clearly suffer losses in quality. Of the 15 to 20 percent toll on total crop output taken by pests and diseases an important part can be attributed to quality rather than quantity loss.

Risk Measurement

In the preceding section several sources of risk and uncertainty were enumerated, some of which can be quantified and many of which cannot. The problem considered here is that of quantifying the risk element in such a way that it can be applied in a risk model. It appears that the risks encountered in each of the intermediate stages or phases of production can be expressed in summary or in aggregate terms using measures of risk with respect to the final product, that is, physical output and product price. In this case it appears that the best approach to risk measurement is to consider the probabilities associated with the profits and losses of the activities involved.

For use in two of the approaches to risk which will follow, the probabilities will be those which quantify the occurrence of yields and prices which fall short of (in bad years) or exceed (in good years) their normal, or modal, values by some specified percentage. That is, the frequencies are noted with which values above or below the normal values of yield and product price are observed. These non-normal values, grouped by percentile intervals, express the magnitudes by which the observed values differ from the normal values. The probabilities of experiencing values above and below the normal value for the activity are calculated.

In the example which follows the probability of a low and a high yield is calculated, as well as the expected value of yield in any given year (Table 2). Based on these data the probability of having a low yield is .20 (i.e., 8/40). Given that a bad year will occur the following probabilities can be calculated describing the magnitude of yield loss:

1. Probability of realizing .90 (i.e., 450/500) of a normal crop is .25.
2. Probability of realizing .80 (i.e., 400/500) is .375.
3. Probability of realizing .70 (i.e., 350/500) is .25.
4. Probability of realizing .40 (i.e., 200/500) is .125.

The expected value of yield in a bad year (Y_b) is

$$E[Y_b] = 500\ [.25(.90) + .375(.80) + .25(.70) + .125(.40)]$$
$$= 500\ [.75]$$
$$= 375.$$

Similarly, the expected yield in good years can be calculated. Given a good year the probability that yield will be 550, or 1.10 of a normal

Table 2. Hypothetical Probabilities of Yield

Category	Yield	Number of Observations	Probability
Normal or modal (Y_n)	500	26	.650
Low or below normal:	375	8	.200
	450	2	.050
	400	3	.075
	350	2	.050
	200	1	.025
High or above normal:	565	6	.150
	550	4	.100
	600	2	.050
Total or mean	485	40	1.000

yield, is .667, and that it will be 600, or 1.20 of a normal yield, is .333. The expected yield in a good year (Y_g) is

$$E[Y_g] = 500\ [.667\ (1.1) + .33\ (1.2)]$$
$$= 500\ [1.13]$$
$$= 565.$$

The probability of having a good year is .15 (i.e., 6/40). Thus, the expected yield at the beginning of each crop period is calculated as follows:

$$E[Y] = P(Y_g)\ (E[Y_g]) + P(Y_n)\ (E[Y_n]) + P(Y_b)\ (E[Y_b])$$
$$= (.15)\ (565) + (.65)\ (500) + (.20)\ (375)$$
$$= 485.$$

The above procedures can be repeated for lower and higher than normal prices. At the farm level the probability of occurrence of any price (P_y) is considered independent of yield, thus the probability of a combination of yield and price is the product of the separate probabilities. However, if the farm yield is correlated with the area yield and the area production is sufficient to affect price, then there may be an inverse correlation between farm yield and farm price. In this three-level (low, normal, and high) model, when price is independent of yield, there are nine possible combinations of price and yield (i.e., of gross income) and nine corresponding probabilities of the occurrence of each combination (Table 3).

In a continuation of the above example, let the probability of a normal price be .75. Then, the probabilities of the various combinations are: a low yield with a normal price .15 (i.e., .20 x .75), a high yield with a normal price .11 (i.e., .15 x .75), etc.

Table 3. Probabilities of Yield-Price Combinations[a]

Price Level	Yield Level		
	High	Normal	Low
High	P_{11}	P_{12}	P_{13}
Normal	P_{21}	P_{22}	P_{23}
Low	P_{31}	P_{32}	P_{33}

[a]Where, $P_{ij} = P(Y_i)\ P(P_{y_j})$ $\quad i = 1,2,3$; $j = 1,2,3$

and 1 = high
2 = normal
3 = low

The expected value of gross (and net) income can be determined using the calculated probabilities of low, normal, and high yields and prices, and the expected value of each yield and price. Using the notation from Table 3, the following equations express the expected income (E[N]) for a crop,

$$\begin{aligned} E[N] = {} & P_{11}\ (E[Y_g]E[P_{y_g}]) + P_{12}\ (E[Y_g]E[P_{y_n}]) + P_{13}\ (E[Y_g]E[P_{y_b}]) \\ & + P_{21}\ (E[Y_n]E[P_{y_g}]) + P_{22}\ (E[Y_n]E[P_{y_n}]) + P_{23}\ (E[Y_n]E[P_{y_b}]) \\ & + P_{31}\ (E[Y_b]E[P_{y_g}]) + P_{32}\ (E[Y_b]E[P_{y_n}]) + P_{33}\ (E[Y_b]E[P_{y_b}]). \end{aligned}$$

Expected profit ($E[\Pi]$) would be

$$E[\Pi] = E[N] - \text{Cost}.$$

Risk and Crop Choice

After establishing the probabilities associated with yields and prices, the selection of a crop or crop combination is governed, in large part, by the farmer's income objectives. Objectives can vary from conservative loss minimization and income stabilization programs to the more speculative goal of profit maximization. In the following section, four income goals and the appropriate action needed to realize these goals are discussed. The four goals are:

1. Maximizing the probability of realizing a selected income level.
2. Minimizing expected losses.
3. Maximizing rate of return to owned capital.
4. Maximizing profits.

Maximizing the probability of realizing a selected income level

The level of income to be considered here lies somewhere between subsistence and the level of living to which the farmer is accustomed. The objective is to stabilize the lower limit of annual income. The basic idea of the approach to a risk situation is to guarantee with a high degree of probability that the farmer will earn the money necessary to provide adequately for himself and his family. With sufficient land the farmer may undertake two distinct programs, one, the guarantee of minimum income, and, two, production according to some other income goal.

Figure 1 illustrates the results of adopting the alternative of stabilizing the lower income limit. The income level selected as the minimum acceptable income is Π_m. In order to achieve this level of

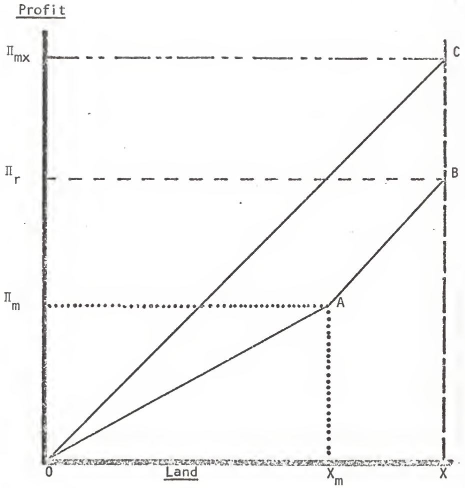

Figure 1.--Maximizing the Probability of Realizing a Selected Income Level

income with a high probability, X_m units of land are planted in a low risk crop or crop combination in the first semester (or in the crop season if there is only one). The remainder of the available land $(X-X_m)$ can then be put into a higher risk, but higher mean earning, crop in order to maximize profit (or other goals can be pursued, such as maximizing return to capital). Assuming constant net returns per unit of land, profit is a linear function of land. In Figure 1, the two-stage combination of stabilizing an income floor and maximizing profit, for example on X land units, is given by OAB with profits given by Π_r. If one were to maximize profits on the entire X units of land, the expected value of profits would be Π_{mx}. The difference in expected earnings between the two activities is equal to $\Pi_{mx} - \Pi_r$, which is the expected annual or semestral cost of the security given by the lower risk option.

<u>Minimizing expected losses</u>

A second possible income goal of farmers, and also a conservative response to the risks in agriculture, is to minimize the expected value of loss in bad years. Losses occur when the farmer fails to earn the opportunity cost of his owned capital, and the monetary costs of the loss consist of three components. These three components are the alternative earnings foregone by not investing in another activity, the amount of money actually lost, i.e., negative profits, and the penalty interest incurred on the borrowed funds in the investment.

<u>Foregone alternative earnings</u>.--The activity in which a farmer sustains a loss is usually only one of many available investment opportunities. For simplicity the alternative investment of importance will be that which yields the highest risk-free return. Admittedly no

investment is completely without risk, but several investment opportunities can be identified as risk-free for practical purposes. Alternative earnings can be calculated from the rate of return (R) of the alternative investment, and the sum of personal capital (K) committed to the activity in which the loss was experienced. Foregone alternative earnings are equal to R x K.

Negative profit.--Negative profit (Π_ℓ) is the difference between total revenue and total cost, where costs are greater than revenue (i.e., $\Pi_\ell < 0$). This is the farmer's monetary loss--the loss of money which he possessed at one time.

Penalty interest.--Penalty interest (I) is the increase in interest rates when the farmer fails to repay his initial loan within the allotted time. Although the government supervised agricultural loans carry low interest rates for the original loan period, late repayment is frequently negotiated between the lending bank and the borrower. The final agreement between these two parties often includes a higher interest charge on the unpaid balance of the loan (C) than was charged in the original transaction.

The total monetary cost of the loss (T_ℓ) incurred is the summation of the above three elements, and can be expressed in equation form as,

$$T_\ell = RK - \Pi_\ell + CI.$$

The total cost of the loss (T_ℓ) is a function of the amount of owned (K) and borrowed (C) capital invested, and the magnitude of the expected loss (Π_ℓ) associated with a particular activity or crop. A rather good rule of thumb that can be applied is that the T_ℓ will generally be higher in those investments requiring high levels of capital input.

Maximizing rate of return to owned capital

A third possible objective of the farmer may be to maximize the rate of return (R) to his personal capital (K). This objective would be most appropriate in cases where capital is the limiting factor. The estimate of return would be based upon the expected profits in the particular activity, and the rate of return would be the ratio of expected profits to owned capital, that is,

$$R = \frac{E[\Pi]}{K} .$$

Maximizing total profit

Unconstrained profit maximization[6] is the income objective commonly assumed by many analysts, yet, it may involve a high level of risk for the farmer. Frequently the activities that yield the highest profits are subject to the largest income fluctuations (either through output or price instability). Pursuit of unconstrained maximum profits is reasonable only for those farmers who are able to absorb the losses which are incurred in a relatively large number of the production periods. Maximizing profits may be a long- or intermediate-range goal over which time the annual or semester profits approximate the expected profits.

[6]Unconstrained maximization is used here to indicate the condition in which land is the only limiting factor.

CHAPTER III

CHARACTERISTICS OF THE GEOGRAPHIC REGION, AND THE SAMPLE SURVEY

The Region

The area chosen for the present study lies at the eastern end of the cotton region that stretches across most of the Northern Coastal Zone of Colombia. The choice of this area was based upon the following considerations:

1. The region is characterized by widespread use of machinery and capital inputs; thus there was the opportunity to get input-output data on modern capital inputs.
2. The cotton zone is a relatively new agricultural area, and no previous study had been made of agriculture at the farm level.
3. There is an interest in Colombia in an evaluation of opportunities for diversifying agriculture in this area.

Physical Characteristics

The area occupies portions of the departments of Cesar and Guajira and is situated on an alluvial plain lying between the Sierra Nevada de Santa Marta and the Cordillera Oriental of the Andes Mountains. The soils are largely medium textured loams, ranging from sandy to clay

loams, which are for the most part well to moderately drained. Generally, the soil pH ranges from 6.5 to 8.0, although there are some areas with high alkalinity where salinity is encountered (19). Annual rainfall varies rather widely within the region, from an average high of 1290.0 mm in the south, to an average low of 782 mm in the northeastern corner of the study area. There is a wet-dry seasonal precipitation pattern throughout the region. There is an eight- to nine-months season, from April to December, that is predominantly a rainy period. April and October are the two months of highest rainfall. There is a short dry period in June and July, which permits the harvesting of first semester crops. The period from the second half of December to the middle of March constitutes the dry season, during which average monthly precipitation is less than 10.0 mm.[1]

Agricultural Patterns

The cotton zone of Cesar and lower Guajira is highly mechanized and modern agricultural inputs are used extensively. These inputs include improved or certified seeds, chemical fertilizers, pesticides, and herbicides. Most of the area is devoted to commercial agriculture, and the important crops--cotton, rice, sorghum, and sesame--are grown on medium-to large-size farms.[2] Of the more than 1.5 million hectares of farmland in Cesar, only 7.2 percent is operated in units of less than 30 hectares (30, p. 10). Although many of the largest farms are

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[1]Precipitation data were taken from records provided by various agencies, including INCORA and IFA.

[2]Average size by crop is as follows: (a) cotton 120 has. (FEDEALGODON and CORAL); (b) rice 40 has. (FEDEARROZ); (c) sorghum 40 has. (ICA); (d) sesame 30 has. (ICA).

primarily in cattle production, the income realized from these operations is much less than that received from crop production. In 1967 income in the department of Cesar was generated as follows (28, p. 6):

Source	Percent of income
Agriculture	85.0
Livestock (cattle)	7.5
Commerce	7.5
Total	100.0

The agricultural entrepreneurs of the Cesar and lower Guajira region can be grouped into three major classes: owner-operators, renter-operators, absentee landlords. Absenteeism is most prevalent in cattle enterprises, although many of the larger cotton and rice producers reside in one of the major coastal cities or even as far from the area as Bogotá. The major consequence of the absenteeism appears to be that much of the land in the larger holdings is underutilized in low earning cattle production.

On the crop producing farms in the area the major portion of the land is rented.[3] The percentage of the land operated by owners appears to vary appreciably among crops, but because of the incomplete listing of farmers the true situation can only be approximated. Usually the

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[3] Distribution of farms by tenure class is as follows:

Crop	Owner	Renter	Source of data
	percent		
Cotton	49	51	(FEDEALGODON and CORAL)
Rice	36	64	(FEDEARROZ)
Sorghum	44	56	(STUDY SAMPLE and ICA)
Sesame	38	62	(STUDY SAMPLE and ICA)

rental contracts are for one year or one cropping period. The effect of having more than 50 percent of the land in major crops cultivated by tenants with short-term contracts is difficult to estimate. Based upon the sample data, correlation coefficients were calculated between tenure and yield for each of the four crops in the study, but no significant correlation was identified. The absence of correlation may possibly be explained by the homogeneity of production practices followed throughout the area due to an almost universal use of technical assistance. The effect of tenure on the use of well irrigation, development of improved pastures, and on the intensity of land use remains an important, unanswered question.

The four major crops grown in the study area are cotton, rice, sorghum, and sesame. The area planted in cotton and rice occupies approximately 80 to 90 percent of the land which is commercially farmed, and production of these two crops accounts for nearly 90 percent of the value of commercial crops.[4] Sorghum and sesame have appeared in recent years as alternative crops to cotton, or to be grown in rotation with cotton.[5] Table 4 shows the relation of the production of cotton, rice, sesame, and sorghum in Cesar to the total production of these four crops in Colombia.

Although the Cesar-Colombia relationships can be easily read from Table 4, the importance of the four major crops within the study area cannot be appreciated without realizing that of the 192.1 thousand

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[4]Calculations of percentages are based on information from various sources.

[5]From 1966 and 1969 the area planted in cotton, rice, sesame, or sorghum ranged from 49.2 to 56.4 percent of total crops in Cesar.

Table 4. Area Planted and Production of Cotton, Rice, Sesame, and Sorghum in Cesar 1966-1969

Crop	1966	1967	1968	1969
<u>Cotton</u>				
1,000 Has.	48.40	64.20	67.70	90.70
1,000 Tons	60.50	99.50	114.60	155.40
Percent of Colombia				
Hectares	29.10	36.70	34.00	38.40
Tons	30.30	37.40	34.30	43.60
<u>Rice</u>				
1,000 Has.	12.60	12.10	11.80	12.00
1,000 Tons	26.50	32.90	46.80	48.40
Percent of Colombia				
Hectares	3.50	4.10	4.20	4.60
Tons	3.90	5.00	6.00	7.20
<u>Sesame</u>				
1,000 Has.	4.10	2.90	3.40	4.30
1,000 Tons	2.60	1.90	2.30	3.00
Percent of Colombia				
Hectares	5.00	4.50	8.50	9.00
Tons	5.00	5.20	9.60	9.40
<u>Sorghum</u>				
1,000 Has.	.20	.35	.90	1.20
1,000 Tons	.39	.67	1.80	2.30
Percent of Colombia				
Hectares	1.00	1.10	2.70	3.30
Tons	1.00	1.00	2.50	2.90

Source: Caja Agraria, <u>Carta Agraria</u>, No. 244, Nov. 1970, Bogotá (5).

hectares in crops in Cesar in 1969 nearly 60 thousand were planted in crops not found in significant quantities in the study area. Thus, instead of the 56.4 percent of cultivated land in the study area being used to produce the four major crops, at least 82 percent is planted in cotton, rice, sorghum, and sesame.

Cotton is the principal crop of the region, and the area is the single most important cotton zone in Colombia. Cotton is planted in July and August and harvested in December to February. Modern technology is used in production. Farm operations are highly mechanized, with the exception of harvesting. Until the 1970-71 harvest, picking was done entirely by hand. For the 1970-71 harvest a few mechanical pickers were imported (one was used in the study zone), but results of this trial are not yet available.

All cotton is ginned in the immediate area, and sold through the various cotton federations in the area[6] at prices which are controlled by IDEMA. Until the 1968-69 crop, costs of production were the lowest in the country. However, due to the rapid rise of insect populations the pest control costs have nearly doubled, thus destroying much of the advantage that cotton producers in this area enjoyed.

In the absence of well irrigation, paddy rice growing is limited to those areas which have access to a continuous supply of surface water. Rice is the most mechanized crop in the region, and even much of the fertilizer is applied by airplanes rather than by the hand methods used in much of the rest of the country. The product is sold locally, principally to mills in Valledupar. On the larger farms, rice

[6]These federations are: FEDEALGODON, CORAL, and ASOCESAR.

is grown either on a year-round basis or is double-cropped, with plantings in April and September, and harvestings in July and December and January.

Sorghum and sesame are just beginning to emerge as important crops in Cesar. The high production costs of cotton in the last two or three years, and the high risk in growing cotton, have led many farmers to shift from cotton, usually to sorghum, or to plant a crop in the "dead" season, after the cotton harvest. Sesame is the primary crop used in rotation with cotton in the interior of the country; yet its adoption is not widespread in Cesar-Guajira. It has a low capital requirement, high resistance to drought, ready markets, and a short growing season.

Most sorghum is sold to IDEMA in the local area. But, because of IDEMA's low prices and stringent quality requirements, several producers sell to PURINA in Barranquilla. PURINA's prices are considerably higher (300 to 400 pesos per ton), but transportation costs absorb most of this difference in price. However, PURINA does not impose strict quality requirements, thus acceptance of the product is nearly always assured.

Sesame is sold to buyers from Barranquilla at the farm, and the buyers pay their own transportation costs. The demand for both sorghum and sesame is greater than the amount which can be presently supplied, and it is likely that the importance of both crops will be increased in the future.

Sample Survey

Focus of the Survey

The present study focuses on commercial agriculture and is limited

to production units within a specified acreage range. It was believed that a study of Colombian agriculture should concentrate on either commercial or subsistence agriculture due to differences in their distinctive characteristics. Commercial agriculture was chosen for this study. The deciding factors in selecting the commercial segment were:

1. The study is to be primarily on a microeconomic level with some final discussion given to policy questions suggested by the analysis. Studies of subsistence agriculture must be greatly concerned with political and social institutions, and macroeconomic aspects must necessarily share at least an equal role with micro-analysis.
2. It was believed that the application of any useful findings of the study would be made faster in the commercial segment due to the more change oriented nature of this segment and the lesser need for institutional change.
3. The accepted formula for the shift from traditional to modern agriculture relies heavily on the use of capital inputs, and the extensive use of these inputs in the commercial sector provides an opportunity to measure their productivity.

The choice of farm size[7] to be included in the study was somewhat

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[7]Farm size here refers to the size of the area planted to a single crop. Thus a 200 hectare unit can consist of 100 hectares of cotton and 100 hectares of rice with each 100 hectares counted as a farm.

arbitrary. The very small units were excluded in that they were either subsistence farms, or because they had production and institutional characteristics peculiar to small units.[8] Extremely large farms were also omitted from the study in the belief that these farms did not typify the majority of the commercial farms in the area, and most absenteeism was encountered on units of this size. In addition, regardless of the outcome of this study, it would be unrealistic at this time to recommend a re-organization of farm holdings in favor of the extremely large farms. Such a recommendation would be directly contrary to the present policy goals being voiced by the National Government which advocates increased land redistribution and fragmentation. Public policy-makers would reject any program which called for greatly increasing farm size and concentration of ownership.

The range for the sample of cotton farms was established at 25 to 500 hectares, and for all other farms the samples were limited to units with more than 10 hectares. The latter restriction has no upper bound, but there were no sorghum or sesame plantings of over 150 hectares. For rice, farm size makes no significant difference in production methods used or in yield per hectare.

Questionnaire

Data were collected in the study zone through personal interviews that were recorded on a prepared questionnaire. The subjects of the

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[8]For example, sorghum farms under 15 hectares and other farms under 10 hectares are not eligible for FFA financed loans (see Chapter IV), and, therefore,often do not employ techniques which characterize commercial farms in the area. For FFA financed loans improved seed and technical assistance are obligatory.

interviews were the farm owners, tenants, and farm administrators with at least five years experience on the present farm. The five-year minimum was imposed on the assumption that data given by memory recall often represent averages over a period of years, or quantities which represent norms. If the administrator had worked for different employers on various farms there would be a strong likelihood that his response would be a blending of these recent experiences on several farms.

The basic purpose of the questionnaire was to obtain detailed production data which included all operations from pre-planting soil preparation to marketing the final output. These data were obtained on an individual crop basis for all crops that the farmer had grown during the two semesters prior to the interview. This cross sectional information was used in the regression and linear programming models.

A final section of the questionnaire was designed to obtain time series data on crop yields and prices over the last 10 years. The farmers were asked to compare past harvests and prices to what was considered normal yields and prices. From this information, frequency distributions were calculated for output and prices, and probabilities were assigned for the occurrence of each particular value.

Sampling Method

The sampling technique used for selecting cotton farms was a stratified random sample. The stratification was made on farm location and there were four size groupings represented--25 to 50, 51 to 100, 101 to 200, and 201 to 500 hectares. The frame used for sampling was the list of cotton producers from the Instituto Colombiano Agropecurario (ICA). These records provided a very acceptable listing as ICA must approve any farmer before he is allowed to purchase the improved, certi-

fied, or imported seed used by nearly 100 percent of the cotton growers in the area. The original plan provided for a 10 percent sample with each stratification represented in proportion to its percentage frequency in the population. Due to the fact that a number of farm operations contained more than one crop, the final sample included about 12 percent of all cotton farms, and consisted of a total of 59 observations.

Neither the method for drawing the sample nor the results of the sample itself were nearly as satisfactory for the other three crops (rice, sorghum, and sesame) as they were for cotton. The lists from which the samples were drawn were not as complete for these crops, nor was there so large a population from which to draw. The National Rice Federation (FEDEARROZ) provided a list of all its members, and records of technical assistance firms and the Caja Agraria (an entity which provides much of the credit to the growers) were consulted to compile a frame from which to select the sample of rice farmers to be interviewed. Unfortunately the last two sources added little to the first, and only a total of 44 farms were identified. The high percentage of tenants in rice farming resulted in not being able to locate many of the growers of the previous years. Similarly, absenteeism contributed to the reduced number of farmers actually available for questioning. The final size of the sample interviewed was only 17 farmers; yet this number represented 39 percent of the total number of rice farms contained in the lists from which the sample was drawn.

Similar circumstances surrounded the sampling of the sorghum and sesame producers. Both crops are very new to the area, consequently there are no federations or associations which represent the growers.

The population had to be constructed from records of credit, technical assistance, and sale of seed. In the case of sesame where ICA was directly responsible for the distribution of improved seed, the lists were probably more complete than for sorghum. The total population for sorghum and sesame were 37 and 32 growers, respectively, and the final sample sizes were 18 producers of sorghum (49 percent of the estimated population) and 21 for sesame (64 percent of the estimated population). Both crops are in an experimental stage for many of the growers, thus out of the small populations several farms were eliminated because they were less than 10 hectares.

CHAPTER IV

INSTITUTIONAL SYSTEMS OF CAPITAL AND CREDIT SUPPLY

The purpose of the work reported in this chapter is to provide a description of the supply of credit and inputs to farmers, and to determine the ways in which credit agencies can influence the amount and forms of capital that the farmers use. In the study area borrowed funds and credit purchases provide a large part of the funds used to purchase and apply farm inputs. A discussion of the availability of credit will serve to complement the findings concerning input productivities. In a later chapter the calculated productivities of inputs are considered in light of the potential supply of credit for financing their acquisition and use.

Commercial Banks and the Caja Agraria[1]

The major institutional sources of short and medium term agricultural credit in the study area and in all of Colombia are the commercial banks and the Caja Agraria. The commercial banks are privately controlled, whereas the Caja Agraria is a quasi-public entity in which the Colombian Government is the major shareholder. By dint of this quasi-public standing, the Caja Agraria's role is somewhat different than that of the other banks. However, the credit extended by both the

[1]The Caja de Credito Agrario, Industrial, y Minero.

commercial banks and the Caja is acquired from private funds, and the government does not contribute funds directly to either's regular credit programs.

In many ways, the channeling of capital through these major credit sources is very similar; thus they are discussed on a parallel basis, noting the relevant differences. A summary of the characteristics of the various types of loans available is given in Table 5.

Ordinary Credit

The ordinary credit offered by the commercial banks and the Caja Agraria is distinguished from the other two types of bank credit by the lack of specific requirements with which the borrower must comply. Ordinary credit is given at the discretion and under the control of the lending agent. This source of credit is the most important supply of agricultural credit in Colombia and in the study area. For the country as a whole, ordinary credit accounts for about 75 percent of all agricultural credit (through formal or institutional channels), and for more than 50 percent in the study area.

Commercial banks

The ordinary credit given by the commercial banking system represents approximately 10 percent of the institutional credit for the agricultural sector. The terms of repayment and the required security for the loan are determined by the individual banks. Interest rates are controlled by the government to the extent that a 2 percent per month (24 percent per year) maximum is imposed. As private investment ventures the ordinary loans of the commercial banks must compete with alternative loan opportunities with respect to risk and return. These

Table 5. Sources of Short Term Agricultural Credit in Colombia

Source	Major Recipients	Annual Interest Rate	Maximum for Loan	Specific Requirements
		Percent	Pesos	
Caja Agraria Ordinary	Small and medium size farms	10	100,000	None
Commercial Bank Ordinary	Various	Up to 24	None	None
Caja Agraria Via FFA	Commercial farms	13	300,000	Farm greater than 10 has., use of improved seed and technical assistance
Commercial Banks Via FFA	Commercial farms	13	None	Farm greater than 10 has., use of improved seed and technical assistance
Law 26 of 1959	Medium to large farms	7 to 9	None	Use of improved seed and technical assistance

Table 5. Extended

Period	Portion of Total 1969 Agricultural Credit[a]	Average Farm Size per Loan	Average Amount per Loan, 1969
	Percent	Hectares	Pesos
Up to one year	70.5	Not available	2,711
Varies	7.4	Not available	46,981
Vegetative period of crop	9.8	48.6	106,432
Vegetative period of crop	7.8	67.2	135,027
Up to 5 years depending on crop	4.5	Not available	141,573

[a]Excluding coffee and livestock.

Source: Superintendencia Bancaria, Fondo Financiero Agrario, and Caja Agraria, unpublished data.

loans are not designated prior to the lending period, which means that all ordinary credit from the commercial banks is awarded by evaluating each loan with respect to the other opportunities which are available at the time.

Caja Agraria

The quantity of credit received under the ordinary credit program of the Caja Agraria represents over 70 percent of the total value of institutional loans in agriculture. The population served by this type of loan is comprised of farmers with small-(total capital value of less than 300,000 pesos) and medium-(capital value between 300,000 and 1.5 million pesos) sized farms. The maximum amount of credit per hectare is fixed, as is the overall maximum per semester which can be given to any one farmer.[2] The maximum amount per hectare is based upon the calculated variable costs for the particular crop (Table 6), and the allowable financing is set at 90 percent of these costs for small farms and at 70 percent for medium farms.

In addition to funds derived from its regular banking practices, the Caja Agraria receives money from contributions required by law, from the commercial banks for use in financing agricultural development. Basically, these regulations stipulate that a certain percentage of the several classes of funds which are controlled by commercial banks (e.g., savings, cash on hand, etc.) must be invested, via loans, in the agri-

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[2]100,000 pesos is the maximum loan which is not earmarked for specific purposes. In addition, the farmer is eligible for 100,000 pesos to be spent on improved seed, and 100,000 pesos worth of inputs purchased directly from the Caja Agraria (i.e., credit in kind).

Table 6. Ordinary Credit Available per Hectare Through the Caja Agraria

Crop	Total Financeable Variable Cost/ha.[a]	Maximum Financing per Hectare Available	
		Small Farms	Medium Size Farms
	---------------------- pesos	----------------------	----------------------
Cotton	4,140	3,573	2,779
Rice	4,860	4,180	3,220
Sesame	1,569	1,358	1,056
Corn	1,832	1,525	1,187
Beans	2,023	1,720	1,337
Wheat	2,293	1,907	1,484
Potatoes	7,840	6,155	4,789

[a]Financeable costs are total costs excluding rent, interest, insurance, and administration.

Source: Caja Agraria, 1970, unpublished data.

cultural sector. Two methods are employed to accomplish this end. Agricultural bonds are sold by the Caja Agraria to the commercial banks which are compelled to purchase an amount in proportion to their assets. The second source of money for the Caja is the difference between the obligations to the agricultural sector and the amount actually loaned to it by the commercial banks. This difference must be invested in development bonds. The proceeds from both classes of bonds are then loaned to the agricultural sector by the Caja Agraria.

As the sole recipient of funds requisitioned for agricultural development loans, the Caja Agraria is responsible for allocating what constitutes the government's major capital contribution, albeit indirect, to the agricultural sector. The Caja Agraria must grant all loans applied for by those farmers qualifying under the definitions of small or medium farms, except for those from farmers who have proved, in previous experience with Caja Agraria, to be unacceptable credit risks.

A comparative note

The major differences between the ordinary credit of the commercial banks and the Caja Agraria can be traced to the objectives of each. As stated earlier, the loans to agriculture by the commercial banks are made as competitive investments. The aim of the Caja Agraria, however, is to provide the loan recipients with opportunities to invest in agricultural activities which would be unavailable otherwise. Frequently, these farmers would not qualify for or would find it very difficult to obtain credit from other sources.

The average amount of credit per loan (see Table 5) is many times greater for the commercial banks than for the Caja Agraria. This difference clearly implies one of three situations: the average farm size

per loan is much smaller for the Caja, the average loan per land unit is larger for the commercial banks, or both conditions exist simultaneously. Based upon the allowable financing per hectare for the Caja Agraria (Table 6) it can be deduced that the national average for farm size per loan is between one and two hectares, whereas that for the commercial banks would be more nearly between 10 and 15 hectares.[3]

Fondo Financiero Agrario

The Fondo Financiero (FFA) was created in 1966 by the Colombian Monetary Board to finance commercial agriculture and to regulate and increase production of short-term (less than one year) food and industrial crops, encourage the increased use of modern inputs, and raise the amount of private investment in the agricultural sector (29, p. 20).

The commercial banks and the Caja Agraria are obligated to contribute to this fund based upon a percentage of their cash holdings. The money is then used as counterpart funds to bank and Caja loans in the proportion of 65 percent FFA to 35 percent bank or Caja participation. The interest rate charged to the borrower for use of credit under the FFA system is 12 to 14 percent. However, the return to the bank or Caja Agraria on its own money is nearly 23 percent.[4]

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[3]Because of the lack of data regarding average farm size per loan this rough estimate has been used. The great disperity between the values for each source of credit allows one to gain insight into the nature of each in spite of the lack of precision of measurement.

[4]The interest charge is 13 percent less 0.5 percent for administration costs. Thus, the banks receive 12.5 percent net interest on the total loan. However, the participation of the bank is 35 percent of the loan value, with the remaining 65 percent being rediscounted through the Fondo, with a rediscount charge of 7 percent. The return then to the bank on its contribution is nearly 23 percent. This can be seen more clearly in the following example: Let 100 pesos be the

Unlike the ordinary credit discussed earlier, FFA credit carries certain stipulations which must be met to qualify for the loans. These stipulations are that the farm be greater than a given minimum size, the farmer use improved seed, the farmer use technical assistance from an approved agronomist, and that the farm be mechanizable. Each loan must be approved by the FFA, which provides some measure of guarantee that these conditions will be met. Payment of the loan is in two installments; the first installment, 60 percent of the total loan, is paid to the farmer before planting, and the second installment is paid approximately six weeks after planting, when it is verified that the farmer has fulfilled the seed and technical assistance requirements.

The purpose of FFA credit is to supplement the capital of the farmer, and specifically to provide additional capital to be spent on modern inputs--especially improved seed, pesticides and fertilizer. Thus, the loan covers only 40 to 60 percent of total variable costs of production, with the major portion allocated for these specific inputs and advanced techniques of cultivation. The amount of credit available per hectare is determined from cost calculations made by the

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amount loaned by a commercial bank. It would receive 12.50 pesos net return through interest charges. Upon rediscounting 65 pesos with the Fondo, and paying 7 percent, the bank remains with 7.95 pesos which is 22.7 percent of its 35 pesos commitment.

\$100.00	original loan		
12.50	net interest received by bank	\$12.50	
		- 4.55	
		\$ 7.95	interest earnings net of rediscount charge
65.00	amount rediscounted with Fondo		
x .07	rediscount rate	$\frac{\$7.95}{\$35.00}$	= .227 return to bank's capital.
\$ 4.55	rediscount charge		

FFA (Table 7), but there is no predetermined maximum on the total amount of credit that may be extended to any one farm.[5]

Credit from the FFA is available in only 16 geographic regions of Colombia, in two of which (Cesar and the Lower Guajira) lies the study zone. The cotton zone in these two regions characterizes precisely the conditions in which the FFA was designed to work. Here the FFA plays a much more important role than in the country as a whole, as is illustrated in Table 8. Credit from ordinary bank loans and through FFA replace that extended elsewhere under the Caja Agraria ordinary credit program.

Interestingly, in a country presumed to be short of agricultural capital, the money programmed under the FFA is not completely utilized:

Semester	Loans granted as percentage of loan money allocated to FFA
1966B	80.2
1967A	84.0
1967B	90.9
1968A	93.8
1968B	83.9

It is generally believed that the quantity of credit being offered via the FFA, for the purposes intended, is sufficient, and for some crops an over-supply exists due to the restrictions which disqualify a large number of farmers for FFA credit (29).

Law 26 of 1959

Law 26 states that commercial banks must commit the equivalent of

[5]For the Caja Agraria there is a 300,000 peso maximum, but this is a Caja Agraria, not a FFA, regulation.

Table 7. Fondo Financiero Agrario Financing for Cotton, Rice, Sesame, and Sorghum

Crop	Costs 100% Financed	Costs Financed at Less Than 100%	FFA Total Cost/ha. Estimates	FFA Total Credit/ha.	Portion of Costs Covered by Credit
			------- pesos	---------	--- percent-----
Cotton	Application of fertilizer and pesticide, fertilizer purchase, hand cultivation, interest, seed purchase, technical assistance, and weed control.	Machine cultivation, harvesting, insecticide purchase, pre-planting soil preparation, and planting.	5,700	2,500	43.9
Rice	Application of fertilizer, insecticide, fungicide, and herbicide, interest, irrigation, seed purchase, and technical assistance.	Purchase of fertilizer, insecticide, fungicide and herbicide.	6,500	3,400	52.3
Sesame	Hand cultivation, harvesting, interest, pest control, seed purchase, and technical assistance.	Machine cultivation, pre-planting soil preparation, and planting.	2,280	1,200	52.6

Table 7. Continued

Crop	Costs 100% Financed	Costs Financed at Less Than 100%	FFA Total Cost/ha. Estimates	FFA Total Credit/ha.	Portion of Costs Covered by Credit
			------- pesos -------		---- percent ----
Sorghum	Application of fertilizer and insecticides, interest, purchase of fertilizer, seed and insecticide, technical assistance, and weed control.	Harvesting, pre-planting soil preparation, and planting.	2,790	1,300	46.6

Source: Fondo Financiero Agrario, 1970, unpublished data.

Table 8. Bank Credit in Cesar, 1969

Source	Total Amount	Share of Bank Credit	Share of Bank Credit in Colombia	Avg. Size of Farm	Avg. Size of Loan
	mil. pesos	percent	percent	hectares	hectares
Caja Agraria Ordinary	253.7	42.2	70.5	N.A.	7,345
Commercial Banks Ordinary	62.9	10.5	7.4	N.A.	88,242
Caja Agraria Via FFA	179.7	30.0	9.8	87.2	191,963
Commercial Banks Via FFA	101.9	17.0	7.8	127.1	273,088
Law 26 of 1959	2.2	0.3	4.5	N.A.	182,066

Sources: Superintendencia Bancaria, Fondo Financiero Agrario, and Caja Agraria, unpublished data.

15 percent of their year end cash on hand to loans in the agricultural sector, which includes crops, livestock, and fisheries. Depending upon the investment, the period of the loan varies from one to five years with a maximum interest rate of 9 percent. The significant difference between these loans and FFA loans is that the private sector (i.e., the commercial banks) makes the choice as to who receives the loans. There is no control by any public agency. The vast majority of Law 26 money goes to finance the livestock industry. It plays a relatively minor role in financing short-term crop production. Table 5 indicates the percent of total credit composed of Law 26 loans, and only a small part of the indicated contribution is to crops.

Summary of Available Bank Credit

Bank credit in Colombia is available under several different programs. Those discussed here are the main sources of short-term credit for crop production. For the study area in particular there appears to be no important shortage in the lending capacity for the agriculture of the zone. The interest rates are low when compared with the average rate of return in crop production of 30 to 40 percent.[6] From the banking side this return is also acceptable. The FFA rediscounted loans pay 22.7 percent on own capital, and banks can charge up to 24 percent for ordinary loans. Even the Law 26 interest rate of 9 percent is not very far from returns in some alternative investments. In 1969 an average return on bonds was 11 percent and on stocks on the Bogotá exchange it was 9.7 percent (3).

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[6] Based on sample data.

Credit from Input Suppliers

In addition to the credit offered through the banking facilities, the commercial sector acts as an important source of capital. The principal agents for this type of credit are the associations of cotton growers and of rice growers, and to an extent the merchants dealing in agricultural inputs.

Three cotton associations operate in the study zone, the Federación Nacional de Algodoneros (FEDEALGODON), Corporación de Algodoneros del Litoral (CORAL), and the Asociación de Algodoneros del Cesar (ASOCESAR). Each of these associations performs several services for its members, one of which is providing credit in the form of deferred payments for purchased inputs. Fertilizers, pesticides, herbicides, and several other types of inputs may be bought on credit through these organizations, and payment made after the crop has been sold. The cost of the loan is paid in the form of higher prices for the inputs when bought on credit than for those paid for at the time of purchase. The charge is approximately 4.6 percent for CORAL and 6.4 percent for FEDEALGODON. It is estimated that the average member obtains 1,000 pesos of credit per hectare per year, which is in addition to the amount received through the banking system. In the case of FFA credit, the 2,500 pesos allowance for a hectare of cotton would be raised to 3,500 pesos total credit. The lower interest charges of the cotton associations, coupled with prices which are lower than local retail prices, enable the credit users to enjoy a cost advantage over nonmembers.

The Federación Nacional de Arroceros (FEDEARROZ) functions for the rice growers in much the same way that the cotton associations serve the cotton farmers. Credit for input purchases is offered for 90-,120-,

or 150-day periods. Purchase procedures differ between fertilizer and other inputs. When buying fertilizer the farmer must pay 40 percent of the value in cash and may obtain the remainder on credit. The interest charges are approximately 6.6, 8.2, and 9.7 percent for 90-, 120-, and 150-day loans, respectively. The charges on loans for pesticides are higher; however, no initial payment is required.

The commercial suppliers of inputs perform a very limited role in the credit programs of the study region. Because of a previous high incidence of non-repayment of debts, there is much reluctance to allow credit purchases. The major sources of credit purchases in the past were the large producers and distributors, including Shell, Esso, and Proficol (a Colombian firm). Present credit from these suppliers is now restricted largely to previous borrowers. The terms and interest rates were not obtained in that the credit is provided on a personal and confidential basis.

Conclusions Regarding Institutional Credit Supply

The consensus among policy-makers and public officials is that the supply of credit in the study zone is adequate to achieve the major objectives of increasing output by modernizing production techniques and expanding crop area. The loans provided through the public agencies are meant to supplement the personal capital of the farmer and not to replace it. Here, however, lies a major shortcoming of the system. Private capital is in fact being withdrawn from the agricultural sector and borrowed funds substituted.

The publicly controlled or sponsored loan programs do not impose any criteria of need on the part of the borrower; thus, both wealthy

and poor farmers are eligible for loans. Control over the use of funds is ineffective and much of the credit is actually used in agricultural activities other than those specified in the credit agreement, or is invested outside of the agricultural sector altogether. This misuse and escape of funds leads to an apparent, and sometimes real, shortage of capital in agriculture. Attempts are made to remedy the supposed shortage by increasing the credit supply, which, in turn, induces more private capital to be withdrawn. These spirals of public credit (upward spiral) and private capital (downward spiral) invested in agriculture create a highly speculative atmosphere in the agriculture of the study area where the farmers are largely risking borrowed money obtained at relatively low interest rates.

CHAPTER V

INPUT USE AND PRODUCTIVITY IN THE STUDY REGION

Input Characteristics

Input Aggregation

A necessary consideration when one is estimating production functions by means of regression analysis is the selection of the variables. Generally, due to the large number of inputs into the production process, it is impossible to include in a computationally feasible model all elements which affect output. Thus the matter of combining individual inputs into input classes is encountered by the analyst.

When approaching this matter of input aggregation two elements should be considered. First, from a practical standpoint how much aggregation is necessary? Data collection as well as computational problems will frequently require that there be some grouping of inputs. The second element focuses on the criteria used to form input classes. In these criteria the purpose and objective of the analysis, and the nature of the inputs, should be considered.

When combined optimally, inputs that are perfect complements should be combined as well as those which are perfect substitutes (32; 4, pp. 137-45; 15, pp. 215-7). However, perfect complements and perfect substitutes are encountered infrequently in farm sample data. Under conditions where less than these perfect relationships are found,

aggregation must be somewhat arbitrary but these relationships are the relevant guidelines.

Definition and Measurement of Inputs

The three basic input classes used in the regression analysis are machinery, labor, and non-traditional cash inputs (NCI). The machinery variable is measured in tractor hours and sums the time spent in tractor powered operations associated with crop production. Other types of machinery time, for example combine harvesting, are not included in the machinery variable. Combining is not entered as part of total machine time as over 90 percent of the combining is done on a contract basis and is not controlled by the individual farmer. The labor input is measured in man hours, and is net of machinery operator time. It was felt that including both machine time and operator time artifically creates two variables where only one input unit exists; that is, these two inputs are perfect complements.

The last major class of variables is termed non-traditional cash inputs (NCI). These inputs include pesticide, herbicide, fertilizer, and improved seed. In the final forms of the production functions in this study the composition of the NCI variable differs among the crops as follows:

1. Cotton--fertilizer, herbicide, and insecticide.
2. Rice--Fertilizer, herbicide, pesticide, and improved seed.
3. Sesame--improved seed only, denoted by S.
4. Sorghum--no NCI variable is included.

The decision as to which inputs to include as regression variables was made for each crop based upon actual use. In some cases an input was omitted because it was not generally used in the production of the par-

ticular crop (e.g., fertilizer in sesame production), and in other cases the quantities and qualities of the input were too uniform among farms to significantly contribute to the explanation of yield variation (e.g., improved cottonseed).

The combination or aggregation of these non-traditional inputs into one input group was done in an attempt to compare the productivity of this class of inputs with other input classes. The major disadvantage of this aggregation is that information with respect to the individual items in the group is not given. However, for purposes of the present study, it was considered more important that the analysis indicate the productivity of the cash input group, and at what levels it should be used.

The results of the analysis indicate the productivity of the NCI input as it is used in the area. The aggregate NCI input is defined by the components as combined in present practices, that is, by the combination of pesticide, herbicide, fertilizer, and seed prevalent in the region.

For each of the four crops included in the study, coefficients for production functions were derived by means of multiple regression. Linear programming was used to determine the combination of crops that would maximize net returns to capital with the existing resource use and technology.

Regression Analysis

The production function chosen for each crop was selected from several functions having alternative forms and independent variables. In the preliminary analyses, linear, quadratic, and cubic forms of the

independent variables and interaction terms were tested. The selection of the final equation for each crop was based upon the extent to which it was believed to describe observed conditions in the area, and upon statistical indicators of significance. The statistical criteria included the student's "t" values for individual variables, and R^2 values for the function as a whole.

Generally the level of significance of the regression coefficients was $\alpha = .05$ or lower. However, several variables were included in the final production functions for which the coefficients were significant at the $\alpha = .20$ or $\alpha = .25$ levels. These latter levels were considered acceptable given the nature of the data used. The data were obtained by interviews and were based on recall, not written records. The sizes of the samples were small and this may have contributed to the lower confidence levels for a number of coefficients. Also, it is believed that these results would provide useful guidance in any future investigation and experimentation.

Cotton

The following production function was derived for cotton:

$$Y = -3266.82 + 253.10\ Mp - 25.00\ Mp^2 + 23.92\ L - .038\ L^2 + 1.812\ (NCI) - .0011\ (NCI)^2 + .00000022\ (NCI)^3$$

where:

Y = yield of seedcotton in kilograms per hectare

Mp = tractor hours per hectare in soil preparation (pre-planting)

L = hours of labor per hectare

NCI = value of fertilizer and insecticide per hectare, in pesos.

In Table 9 the values derived from this equation and the mean value of each input based upon sample data are summarized.

Table 9. Production Function and Sample Means for Cotton

Variable	Regression Coefficient	Standard Error	Input Level: To Maximize Output	Input Level: To Maximize Profit	Input Level: Mean	MPP at Mean	MVP at Mean	MPP at Maximum Profit	Input Price, Pesos
Mp	253.100**	87.500	5.1	4.8	5.3	-10.2	-37.74	11.8	44.00
Mp^2	-24.978**	7.110							
L	23.916**	2.970	314.7	301.4	221.8	7.1	26.27	1.01	3.75
L^2	-0.038**	0.006							
NCI	1.812[a]	1.469	1,444.0	970.0	1,523.1	-0.02	-0.07	0.30	1.08
$(NCI)^2$	-0.0011[a]	0.0009							
$(NCI)^3$	-2.2×10^{-7}[a]	1.8×10^{-7}							
a	-3,266.82								
R^2	.85								

**Significantly different from zero at α =.01.

[a]Significantly different from zero at α =.20.

It is indicated by the regression analysis that there is an overuse of machinery in soil preparation. The average use is above the maximization level, thus the farmers are actually lowering yields, as well as incurring unnecessary expenses. Two possible causes of the negative effect of machinery have been hypothesized. The first is that excess preparation is harmful to the soil structure, and with its deterioration yields are adversely affected. Deterioration of the structure is usually in the form of compaction which disrupts normal drainage, airflow, and root growth. The second possibility relates to the techniques of performing the various preparatory operations. It has been observed that in the course of pre-planting preparation the natural drainage of the fields is often interrupted by the irregular surface which is created.[1] When the rainy period resumes, large pools of standing water collect and cause serious damage to (sometimes killing) the cotton plants.

Average use of labor in the area is well below the indicated maximizing level. This may reflect the fact that during the two months of the cotton harvest there is a shortage of labor in Cesar. It has been estimated that up to 20 percent of the cotton produced in the area is not harvested due to this shortage. This figure is probably an exaggeration of the problem.

The labor variable used in the cotton production function includes harvest labor. It was felt that the quantity of labor used during harvesting had an important effect on the realized yield of the product.

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[1]This possibility was suggested by a member of the Agricultural Engineering section of the University of Nebraska's Colombia Mission who is conducting research on farm machinery use in the study area.

The amount of cotton removed from the field is related to the size of the picking force which can decrease the length of the harvesting period and the chances of loss due to rain damage or to the fiber falling from the plant.

A second use of labor which may also help to explain the high marginal productivity is hand cultivation or weed control. After the emergence of the cotton plant, herbicides are not used in weed control, and two to four hand cultivations are the major means of weed control during most of the growing period. These hand methods of weed control could have a significant positive effect on yields.

The marginal returns to NCI (fertilizer and pesticide) were negative at the mean level of use. A regression analysis in which fertilizer and pesticides were entered as separate variables indicated that this negative result was due almost entirely to pesticide use, as cotton showed virtually no response to fertilizer at the level of application observed. The problem of low level fertilizer use in cotton production stems, in large part, from ICA recommendations. A recent analysis of experimental data indicated, tentatively at least, that the quantities of fertilizer applied in ICA test-plots were producing in Region I of the production function, and that additional amounts would greatly increase output. In many instances the levels were even too low to have reached the point of increasing returns and the production surface was essentially flat over the range of observations. Similarly, the results of the analysis of fertilizer use in the study zone showed a very weak positive response which was, from a practical standpoint, linear. When fertilizer was later included in the regression equation as a cubic expression the mean level of use fell in Region I of the

production function. These corroborating findings from ICA and from farm data imply that fertilizer is being underemployed, both in experimental work and on commercial farms.[2]

The analysis indicates that the current quantities of pesticides being used are decreasing yields and greatly increasing costs. Pesticides and their applications account for approximately 20 percent of the total costs of cotton production. In the sample of 59 farms these costs ranged up to 2,400 pesos per hectare--to more than 40 percent of the average costs of production per hectare.

The decrease in yield associated with increases in the level of pesticide application is difficult to understand. Two possible, and reasonable, explanations for this phenomenon were encountered. Entomologists in ICA expressed the belief that the applications of insecticide at lower than recommended dosage could be a possible cause of the negative relationship between pesticide expenditures and cotton yields. Low level applications would not destroy the insect pests as completely as desired, even though they would reduce the population. The remaining pests would continue to destroy the crop. The two unfavorable results of this situation would be that a greater number of applications of insecticide would be required, and that there would be a nearly continuous destruction of plants due to the failure to destroy the pest population. The symptoms of this condition would be those

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[2]The average levels of fertilizer application were:

	Kgs. per hectare	Lbs. per acre
Nitrogen	82.5	73.5
P_2O_5	19.1	17.0
K_2O	16.2	14.4

indicated by the regression analysis, higher pesticide costs associated with lowered yields.

An examination of the doses used on the sample farms revealed that the above explanation could well be applicable in many instances. In the case of the two most widely and often used insecticides, Toxafeno DDT and Methyl Parathion, it was observed that over 60 percent and 75 percent, respectively, of the applications were below ICA recommended levels. With respect to Toxafeno DDT almost two-thirds of the cases of low dosage had application levels of only 50 percent of the recommended level, and for Methyl Parathion the percentage was only slightly higher.

The inverse relationship between expenditures on insecticide and crop production has a second possible explanation. The use of chemical control not only affects the pests at which it is directed, but also affects, and possibly to a greater extent, the parasites and predators of the insect pests.[3] That is to say, insecticides are very successful in decreasing the biological or natural controls of the insect populations. There is a tremendous decrease in the incidence of pest deaths due to natural causes in areas which are under heavy or frequent insecticide applications. It is estimated that much of the initial control of cotton pests could be accomplished through biological control, or a combination of biological and chemical control at costs substantially below present ones (7).

Several conditions or practices related to spraying cotton in the

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[3]The constant movement of predators and parasites in search of victims and hosts increases the probability that they will be exposed to areas in which insecticide was applied. In addition, many of the beneficial creatures move through the upper regions of the plants which increases their exposure to the toxic chemicals.

the area contribute to the high cost and decreased yields which are explained by the reasons given above (1, pp. 173-9):

1. Insecticide application is frequently ordered by the agronomist giving technical assistance before the insect population is sufficiently great to actually cause significant plant damage.
2. Often whole farms or crop areas are sprayed when the infestation is in fact localized.
3. Attention is not given to optimal times for spraying, thus it is much less effective than could be expected. Spraying is done during the day when many pests have migrated to the lower sections of the plant, and, hence, escape much of the insecticide applied. Most spraying should be done during the morning and late afternoon feeding periods.
4. The wrong chemicals are prescribed, or the prescribed ones are not available.
5. Attempts are made to destroy the insects after they have reached stages in their life cycles in which they are little affected by the pesticides.
6. Highly toxic, broad spectrum insecticides are used when less toxic, more specific ones would work as well with less damage to the beneficial fauna in the fields.

<u>Rice</u>

The following production function for rice was estimated:

$$Y = -108605.0 + 11028.9M - 1071.82M^2 + 33.56M^3 + 3191.1L - 59.13L^2 + 0.34L^3 + 21.1\,(NCI) - 0.0052\,(NCI)^2 + 799.7F_D$$

where:

Y = yield of rice in kilograms per hectare

M = tractor hours per hectare (not including combine harvesting time)

L = man hours of labor per hectare

NCI = expenditures on fertilizer, insecticide, herbicides, and improved seed, in pesos

F_D = dummy variable for method of fertilizer application, 0 = hand application, 1 = mechanical application.

A summary of the findings is given in Table 10.

In contrast to cotton, it was indicated that there should be an increase in the use of machinery. This result could be due to the increased water retaining capacity of the soil brought about by the changes in soil structure, principally compaction, during pre-planting soil preparation. This effect would be especially significant during the dry semester when water supplies are greatly decreased. The sample data include observations from both semesters, thus water availability may enter as a factor affecting yields and yield variance.

The mean input of labor in the sample was somewhat above the indicated yield maximizing and profit maximizing levels; thus the marginal productivities were negative. The most important cause of high labor input was hand application of fertilizer during the growing season. The substitution of hand application for aerial application decreases the productivity of fertilizer, as many areas receive small amounts of

Table 10. Production Function and Sample Means for Rice

Variable	Regression Coefficient	Standard Error	Input Level: To Maximize Output	Input Level: To Maximize Profit	Mean	MPP at Mean	MVP at Mean	MPP at Maximum Profit	Input Price, Pesos
M	11,028.90[a]	7,145.940	8.7	8.63	8.51	77.8	124.50	27.9	44.00
M^2	-1,071.82[b]	778.510							
M^3	33.56[b]	27.340							
L	3,191.10*	1,404.550	42.7	42.60	49.50	-163.5	-261.60	2.4	3.75
L^2	-59.13*	26.021							
L^3	0.34*	0.149							
NCI	21.10*	7.985	2,028.8	1,963.4	2,074.70	-0.48	-0.77	0.7	1.08
$(NCI)^2$	-0.0052*	0.0021							
F_D	799.7[b]	405.223							
a	-108,605.0								
R^2	.72								

*Significantly different from zero at α =.05.

[a]Significantly different from zero at α =.10.

[b]Significantly different from zero at α =.25.

fertilizer which produce less rice than areas uniformally fertilized. The dummy variable for fertilizer application substantiates this conclusion. The regression equation indicates that the yield associated with mechanical fertilizer application was 800 kilograms higher than when hand application was used (800 is 18 percent of the mean yield on farms in the sample). The mean levels of inputs were relatively close to the optimal levels as calculated from the regression coefficients. The rather long experience of rice growers in the region, and in similar areas in the country, undoubtedly contributed to this condition.

Sesame

The production function calculated for sesame is:

$$Y = -40805.0 - 259.1T + 11711.7M - 1491.4M^2 + 58.6M^3 + 215.1L - 1.43L^2 + .0029L^3 - 29.645S - .575S^2 + 2.52(M)(L) + 9.4(M)(S) - 202.7D_1 + 299.6D_2$$

where:

Y = yield in kilograms per hectare

T = tenure (0 = owner, 1 = tenant)

M = hours of tractor use per hectare

L = hours of labor per hectare

S = expenditures on seed per hectare

D_1 = dummy variable for municipio (town) of San Juan (1 if farm in San Juan; 0 otherwise)[4]

D_2 = dummy variable for municipio of Becerril (1 if farm in Bercerril; 0 otherwise).

[4]The third municipio is Codazzi.

The coefficients, means and derived values for sesame are summarized in Table 11.

The experience with sesame in the study area is very limited. Most of the farmers interviewed had grown this crop for only one or two years and they were still in an exploratory stage in which they were looking for the best combination and levels of inputs. The regression analysis is based on present practices, and it should be kept in mind that the current production practices may be changed as additional experience is gained. Fertilizer, herbicides, and insecticides were not usually applied, and very low levels were used in the few cases in which they were applied. Within the existing system of production only the machine input varied greatly from the optimal level of use. The maximizing level that was estimated for seed indicates a high return to improved seed varieties. There were seven varieties of seed found in the sample of 21 observations. However, the quantity of seed in kilograms per hectare was quite uniform among farms. The implication with respect to seed is that the higher cost seed (imported or domestic) produces higher yields than the ordinary domestic seed.

Sorghum

The following production function was selected for sorghum:

$$Y = 1141.82 + 1475.55M - 106.34M^2 - 231.05L$$
$$+ 6.12L^2 - 0.040L^3 - 8.44(M)(L)$$

where:

Y = yield in kilograms per hectare

M = tractor hours per hectare

L = man hours per hectare

Table 11. Production Function and Sample Means for Sesame

Variable	Regression Coefficient	Standard Error	Input Level: To Maximize Output	Input Level: To Maximize Profit	Input Level: Mean	MPP at Mean	MVP at Mean	MPP at Maximum Profit	Input Price, Pesos
M	11,711.7000*	2,344.600	7.32	7.2	8.75	-30.5	-140.4	9.1	44.00
M^2	-1,491.4000*	292.510							
M^3	58.6000*	11.4600							
S	-29.6400[a]	18.1700	34.00	32.9	31.10	16.8	117.1	0.22	1.08
S^2	-0.5700*	0.2600							
L	215.1000*	51.3200	167.20	147.0	146.90	2.3	10.6	0.82	3.75
L^2	-1.4300*	0.3100							
L^3	0.0029*	0.0063							
(M)(L)	2.5000*	0.7100							
(M)(S)	9.4000*	2.9100							
D_1	-202.7000[a]	126.2700							
D_2	299.6000*	60.5900							
T	-259.1000*	64.2600			0.40				
a	-40,805.0								
R^2	.94								

*Significantly different from zero at $\alpha = .05$.

[a]Significantly different from zero at $\alpha = .10$.

Table 12 gives a summary of regression coefficients, means, and other calculated values.

Like sesame, sorghum is a new crop in the area and very few farmers have more than two or three years of experience with it. There were insufficient data in the sample to calculate effects of pesticide and fertilizer from the regression equation.

The maximizing level of machinery and labor were calculated by the simultaneous solution of their first derivative equations set equal to zero while holding capital at its mean value. The use of labor is substantially below the optimizing level, and it is quite possible that it is also at a level corresponding to Region I of the production function. Given that sorghum is a new crop and that the farmers are not yet committed to it, there is much hesitation toward investing large quantities of inputs in sorghum production. In many cases the producers are searching for a low cost crop to be grown in rotation with cotton, and,thus, are operating at very low levels of inputs. Although the mean machinery use is above the indicated level to achieve optimal output, it is considerably below the amount used in the other crops of the area which indicates that there is an attempt to use machinery at the lowest possible level, and this may be decreased further as more experience is gained.

Input Productivities

The marginal value products (MVP) of machinery, labor, and NCI were calculated using the sample means, ICA's cost of production reports, and the Fondo Financiero Agrario's cost of production studies which serve as a guide to credit. In the input groups there was a wide range of levels of application or use. The following discussion compares the

Table 12. Production Function and Sample Means for Sorghum

Variable	Regression Coefficient	Standard Error	Input Level: To Maximize Output	Input Level: To Maximize Profit	Input Level: Mean	MPP at Mean	MVP at Mean	MPP at Maximum Profit	Input Price, Pesos
M	1,475.550*	570.1237	4.13	4.00	5.42	-84.0	-100.8	32.21	44.00
M^2	-106.343*	54.8962							
L	-231.052*	141.9535	70.70	70.20	48.23	34.4	41.3	2.93	3.75
L^2	6.122*	2.8135							
L^3	-0.040*	0.0178							
(M)(L)	-8.439[a]	5.4109							
a	1,141.82								
R^2	.81								

*Significantly different from zero at α =.05.

[a]Significantly different from zero at α =.10.

marginal value product of each input by crop and by source of data (i.e., sample, ICA, and Fondo Financiero Agrario). Table 13 gives the marginal value products by inputs, crops, and data sources.

Machinery is generally over-used in cotton. Under the present system of production in the area most farms have specialized in only one crop per semester, thus, the errors in machinery allocation cannot be rectified by correcting the proportions of total hours given to each crop. Rather, it is a question of increasing or decreasing the use of machinery in each semester on the particular crop as indicated by the MVPs (Table 13).

Perhaps the major reason for the misuse of machinery is the lack of knowledge of the effects of mechanization on output. In the absence of data on machinery use, the questions of soil preparation and cultivation will continue to be answered by guesswork, and trial and error. The absence of knowledge concerning this phase of production is further implied by the wide range of machinery recommendations and use among the professional workers and among the farmers. The large difference between the optimal use and recommended use with respect to sorghum and sesame primarily stems from the lack of experience in the area with these crops. Recommendations are generally based upon the practices found in other regions of the country.

Generally, the MVPs for labor display the fluctuations between negative and positive quantities that were seen with respect to machinery (Table 13). The MVP of labor as calculated from the sample is the only positive labor MVP among the three calculated for cotton. This result is due to the labor shortage in the study area which does not exist in the cotton zone from which the ICA data were derived, nor is it accounted

Table 13. Marginal Value Product (MVP) of Machinery, Labor and NCI at Three Levels of Resource Use

Crop	MVP of Machinery with Price = 44.00, and Input Quantity Given:			MVP of Labor with Price = 3.75 and Input Quantity Given:			MVP of NCI[a] with Price = 1.08 and Input Quantity Given:		
	at sample mean	by ICA	by FFA	at sample mean	by ICA	by FFA	at sample mean	by ICA	by FFA
	Pesos								
Cotton[b]	-37.7	83.8	-6.2	26.3	-23.3	-11.0	-0.07	0.65	-0.14
Rice	124.5	1,531.0	1,531.0	-261.6	142.4	92.1	0.77	1.40	-9.80
Sesame	-140.4	306.0	1,035.0	10.6	-8.6	30.2	117.10	-107.00	-207.00
Sorghum	-100.8	-	-376.7	41.3	-	-47.2	-	-	-

[a]NCI includes the following: Cotton--fertilizer, herbicide, and insecticide expenditures;
Rice--fertilizer, herbicide, insecticide, fungicide, and seed expenditures;
Sesame--seed expenditures.

[b]The machinery input includes only pre-planting soil preparation operations.

for by the Fondo Financiero Agrario when estimates are made for nationwide use.

The MVPs for NCI indicated by the sample are closely related to the amount of credit which can be obtained for the particular crop. That is, as the percentage of production costs which can be financed by borrowing increases, so does the relative use of these inputs. For sesame approximately 54 percent of the costs can be obtained easily through institutional sources. The basic amount of financing (i.e., from the FFA or the Caja Agraria) is 57 percent for rice, but this does not include the credit which can be received for buying cash inputs from the Rice Federation. The percentage for cotton is at least 64, excluding some of the minor sources of credit. It appears, then, that the farmer is more likely to invest borrowed funds, which he can obtain at relatively low interest rates, rather than his own capital for which the opportunity costs are higher.

The MVPs for NCI based upon the allowances of the Fondo Financiero Agrario are all negative. The high levels of inputs recommended (or at least approved) by this major credit source can be explained in two ways. First, there is constant pressure on the credit agencies from the organized farm groups, in this case the National Cotton and Rice Federations, to increase the amount of credit extended to their members. Increased credit quotas for these crops can be justified only when the production activities for which they are to be spent are shown, and when they are justified by rising costs or changes in recommended inputs or input levels. The most variable portion of production costs for cotton and rice is the amount spent on fertilizer and pesticide. Thus, the increases in credit allowances are most easily allocated to these

two inputs. In view of the heavy emphasis on pesticide application there may be a misallocation of credit between fertilizer and pesticide. If the fertilizer response levels are in Stage I of the production function as indicated in this study, additional financing should be given for purchase of fertilizer rather than for pesticides. The reallocation of credit within the present amount used to purchase modern inputs would yield positive MVPs.

The second possible cause for the negative MVPs of NCI stems from the Fondo Financiero's aim to increase the use of modern inputs in Colombian agriculture. To achieve this goal the incentives to adopt the inputs are made as enticing as possible, and a major strategy is to provide a large measure of help for the farmer who wants to raise his level of technology. Among the inputs and activities for crop production, the cash inputs are invariably those financed at levels between 70 and 100 percent of their cost by the Fondo Financiero Agrario. In its desire to introduce and perpetuate the application of capital inputs the FFA has possibly over-allocated its funds to these factors.

Crop Profitability[5]

Based on the production functions derived from the sample data,

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[5]Profit was calculated by subtracting costs from gross income. All costs were included except the fixed costs of buildings and constructions, and entrepreneurial costs. It was felt that the rent cost included the costs of buildings and constructions. (Generally these fixed costs are quite low on a per hectare basis.) Nearly one-half of the farmers were short-term tenants and it was felt that the landlords established a rent charge which would include a return to their investment in constructions. Since the same rent cost was charged to owners for purposes of land valuation in the study, it can be assumed that this rent would also include fixed costs. Although the cost of the entrepreneur (or decision maker) was not subtracted to calculate profit, a cost was included for administration which covers the "in-the-field" managerial costs. This charge was a standard amount per hectare.

profit functions were evaluated for each of the four crops at the input levels given by ICA, the Fondo Financiero Agrario, and the mean, the output maximizing, and the profit maximizing levels from the sample. Table 14 gives the profits corresponding to these crops and levels of inputs. The most striking feature of the results is that neither the mean (actual use), ICA, nor Fondo Financiero Agrario levels approached the potential profits at the optimum, with the exception of the Fondo Financiero Agrario for sorghum. The heavy emphasis on cotton seems justified when viewed from the potential profit aspect, but much less so for profits presently being achieved.

Table 14. Profit per Hectare for Cotton, Rice, Sesame, and Sorghum Using Calculated and Recommended Input Levels

	Sample				
Crop	Mean	Maximum Output	Maximum Profit	ICA	FFA
	------------------------ Pesos ------------------------				
Cotton	1,099	2,064	2,379	818	1,113
Rice	1,546	2,612	2,643	1,516	-1,907
Sesame	489	1,499	1,561	-14	-1,317
Sorghum	691	949	955	-	403

For those farmers who are seeking alternatives to cotton, or who are considering the possibility of supplementing cotton with a first semester crop, both sesame and sorghum present encouraging indications. Their low costs and competitive profit rates reflect characteristics which are being sought by these farmers.

A different, yet important, conclusion implied by the profit levels is that the ICA recommendations give rather poor results. For cotton they yield lower profits than do present practices (sample mean), and they are substantially below the optimum. The low profit based on ICA recommendations in sesame may not be entirely realistic since ICA recommends weed and insect control which do not enter into the regression equation; these inputs could have considerable effect on yields. There were inadequate data from the sampled farms to permit pesticides to be entered as a variable.

In general, there is a wide gap separating the potential and actual profitability of the four crops. Even under the existing cropping systems profits could be increased.

Linear Programming Analysis

The basic program included all four crops, and employed the input-output data obtained in the sample (see enterprise budgets given in Tables 27 through 30 in the appendix). Two additional programs were calculated using identical input-output coefficients, but with a variation in the number of activities in one and a different objective function in another. The results show the optimum crop combinations under the present systems of production. The second program differs from the first in that rice has been deleted as an activity. This variation was made to conform with the conditions found in some parts of the study area. Generally, irrigation is available for all of the land on a farm, or for none at all. Thus, to prevent rice from entering into the solution when dealing with farms without irrigation, as is the case on the vast majority of farms, this second program was run. The third and

final program varies from the basic one in the objective function. Rather than maximizing profit, this last program maximizes net return to owned capital.[6]

Solutions to each of the programs were calculated for eight combinations of machinery and capital input levels. These levels ranged from unlimited quantities of both inputs to levels below the minimum per hectare requirements for any of the four crops. The levels of machinery (in tractor hours per hectare) are based on estimates of the power supply that would be available if the farmer were to possess a large or a small tractor, or combinations of the two sizes. The capital allowances were made in agreement with potential credit, and high to low personal capital resources.

Another limiting resource was the labor available for cotton harvesting. The maximum amount of labor permitted corresponds to 93 percent of the amount that would be needed if the whole farm were planted in cotton. This restriction is based upon the sample data and represents the average harvest labor input (per kilogram of cotton) from the farms in the lowest quintile of the sample, when ranked by this measure. It was assumed that these farms had a scarcity of labor during this period. The average in the lowest quintile was compared to the average in the upper four quintiles, and it was observed that the former was approximately 93 percent of the latter. The constraint on labor was made in consideration of the region as a whole, rather than from the standpoint of a single farm. If cotton were to be planted on all available land in the second semester, then a shortage of labor would occur

[6]In the linear programming problem capital refers to the total cost of the activity, excluding the costs associated with farm buildings.

on some farms. By restricting the portion of the area planted in cotton it was felt that a more realistic situation could be programmed.

The Basic Program

The objective function of the basic program was to maximize profit. Estimates of profits per hectare for cotton, rice, sesame, and sorghum are as follows:

Crop and semester	Profit, pesos
Cotton (2)	957
Rice (1)	1,086
Rice (2)	1,126
Sesame (1)	652
Sesame (2)	652
Sorghum (1)	728
Sorghum (2)	798

The following are the per hectare machinery and capital levels used in the analysis:

	Machinery, in tractor hours	Capital, in thousands of pesos
Very high (VH)	12.6	6.2
High (H)	10.4	4.6
Medium (M)	7.1	3.5
Low (L)	5.0	2.3
Very low (VL)	-	2.0

The solutions are given in Table 15. The numbers following the crop symbols indicate the proportion of the total farm which should be planted in the particular crop. The net profit per hectare per year for the crop combination is given.

With unlimited capital resources rice planted on the total farm would maximize profits. However, due to its high capital requirements, this proportion quickly decreases as capital restrictions are imposed. Sorghum's low cost and moderate profit allow it to occupy the area withdrawn from rice production, but with the decrease in area devoted to

Table 15. Crop Combinations for Maximizing Profit at Selected Levels of Capital and Machinery Inputs, with Rice Included

Resource Levels[a]	Profit Maximizing Combinations[b]	Annual Profit per Hectare	Annual Rate of Return to Owned Capital
		pesos	
VH-VH	R1 (1.0) R2 (1.0)	2,212	.400
H-VH	Sg1 (.45) R1 (.55) Sg2 (.44) R2 (.56)	1,906	.450
H-H	Sg1 (.45) R1 (.55) Sg2 (.44) R2 (.56)	1,906	.450
M-H	Sg1 (.79) R1 (.21) Sg2 (.77) R2 (.23)	1,678	.500
M-M	Sg1 (.79) R1 (.21) Sg2 (.77) R2 (.23)	1,678	.500
L-M	Sm1 (.58) Sg1 (.37) Sg2 (.87)	1,343	.590
L-L	Sm1 (.10) Sg1 (.77) Sg2 (.27)	1,316	.557
VL-L	Sm1 (.24) Sg1 (.54) Sg2 (.76)	1,153	.567

[a]Capital is indicated by the first symbol and machinery by the second symbol.

[b]C = Cotton, R= Rice, Sm = Sesame, Sg = Sorghum
1 = first semester 2 = second semester

Numbers in parentheses indicate the fraction of total land to be planted in the specified crop.

rice production profit per hectare declines rapidly. When rice finally is forced out of the solution--at the low capital-medium machinery level--cotton cannot compete with sorghum because it requires twice the machinery and capital inputs while yielding only about 30 percent higher profit. Sesame also enters the solution at the lowest levels of resource use due to its very low capital requirement.

Solutions Without a Rice Activity

When rice production is eliminated as a possibility--for land without irrigation--cotton becomes the principal second semester crop at the higher resource levels. It remains an important crop until the low capital-medium machinery input level is reached. This is the same combination at which rice left the solution in the first program. Beginning at this level the solutions of the first and second programs are the same, using low capital consuming sesame, and low capital and machinery consuming sorghum to maximize profits. The profits in the second program are considerably lower than those of the basic one, particularly in the upper resource groups where rice is the major crop in both semesters (Table 16).

Maximizing Returns to Owned Capital

The third program modifies the basic one by changing the objective function from a profit to a rate of return function. The value to be maximized is the rate of return to owned capital,[7] where owned capital

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[7]Rates of net returns to owned capital for the four crops are:

C = .47	Sm1 = .64
R1 = .39	Sm2 = .64
R2 = .43	Sm1 = .51
Sg2 = .56	

Table 16. Crop Combinations for Maximizing Profit at Selected Levels of Capital and Machinery Inputs, Excluding Rice Production

Resource Levels[a]	Profit Maximizing Combinations[b]	Annual Profit per Hectare	Annual Rate of Return to Owned Capital
		pesos	
VH-VH	Sg1 (1.00) C2 (.93) Sg2 (.07)	1,674	.490
H-VH	Sg1 (1.00) C2 (.68) Sg2 (.32)	1,633	.510
H-H	Sg1 (1.00) C2 (.68) Sg2 (.32)	1,633	.510
M-H	Sg1 (1.00) C2 (.28) Sg2 (.72)	1,570	.530
M-M	Sg1 (1.00) C2 (.24) Sg2 (.76)	1,564	.530
L-M	Sm1 (.58) Sg1 (.37) Sg2 (.87)	1,343	.590
L-L	Sm1 (.10) Sg1 (.77) Sg2 (.87)	1,316	.557
VL-L	Sm1 (.24) Sg1 (.54) Sg2 (.76)	1,153	.567

[a]Capital is indicated by the first symbol and machinery by the second symbol.

[b]C = Cotton, Sm = Sesame, Sg = Sorghum
1 = first semester 2 = second semester

Numbers in parentheses indicate the fraction of total land to be planted in the specified crop.

is the total investment less that portion which has been borrowed. Maximizing this rate of return under the conditions which are generally found in the study zone (i.e., the farmer's own funds are fixed in amount at the beginning of the production period, and this period is of a fixed length) also maximizes net returns to total capital invested in the activity (6, p. 62).

Under conditions in which capital, not land, is the limiting factor of production, maximization of the rate of return to capital is a more logical goal. With the objective function in these terms the programming solution indicates that the low capital using crops will yield a rate of return between .54 and .64 over the considered range of inputs. However, it should be noted that per hectare profits are considerably lower than in the previous programs at all but the lowest levels of resource use.

In maximizing the rate of return, only sesame and sorghum enter the solutions (Table 17). Although rice was also included as a potential crop, its high capital requirements excluded it in spite of high profits per hectare. Similarly, the high capital requirements for cotton cause the rate of return to capital to be lower than in the case of sorghum, even though the net income per hectare is considerably higher. The annual rates of return for rice and cotton are .40 and .47, respectively.

Comparison of Profit and Rate of Return Maximizing Solutions

With sufficient capital, farming in the study zone is unrestricted as to which of the four crops, and in what combinations, one is able to

Table 17. Crop Combinations for Maximizing the Rate of Returns to Owned Capital at Selected Levels of Capital and Machinery Inputs

Resource Levels[a]	Crop Combinations[b]	Annual Profit per Hectare	Annual Rate of Return to Owned Capital
		pesos	
VH-VH	Sm1 (.96) Sg1 (.04) Sm2 (.96) Sg2 (.04)	1,312	.636
H-VH	Sm1 (.96) Sg1 (.04) Sm2 (.96) Sg2 (.04)	1,312	.636
H-H	Sm1 (.96 Sg1 (.04) Sm2 (.96) Sg2 (.04)	1,312	.636
M-H	Sm1 (.96) Sg1 (.04) Sm2 (.96) Sg2 (.04)	1,312	.636
M-M	Sm1 (.51) Sg1 (.49) Sm2 (.51) Sg2 (.49)	1,413	.580
L-M	Sm1 (.58) Sg1 (.37) Sm2 (.57) Sg2 (.39)	1,332	.600
L-L	Sm1 (.10) Sg1 (.77) Sm2 (.07) Sg2 (.81)	1,315	.560
VL-L	Sm1 (.24) Sg1 (.54) Sm2 (.22) Sg2 (.57)	1,149	.574

[a]Capital is indicated by the first symbol and machinery by the second symbol.

[b]C = Cotton, R = Rice, Sm = Sesame, Sg = Sorghum
1 = first semester 2 = second semester
Numbers in parentheses indicate the fraction of total land to be planted in the specified crop.

produce.[8] Profits per hectare are the highest for rice production and the .41 annual return to capital is competitive with most non-agricultural investments. In the areas where irrigation is not feasible, for either physical or economic reasons, cotton performs a similar role as rice, with somewhat lower profits per hectare, but higher returns to capital. On farms where land is the limiting input these crops would maximize profits for the farm.

With capital rather than land as the restricting input, the maximization of return to capital investment, not per hectare profit, should be the primary goal. The farmer with low capital resources maximizes profits by maximizing the rate of return to his capital. In Table 18 the rates of return calculated for resource levels in each program are presented and profits per hectare are summarized in Table 19. Only in the low capital levels do the profit maximizing and rate of return maximizing solutions coincide. The most obvious points indicated by these results are that there is no justification for planting cotton when capital supply is at these levels, and that there is a definite difference among optimum cropping patterns for the different resource situations. These differences are rarely recognized in the present recommendations made to farmers in the study area.

Shadow Prices

The shadow price derived from linear programming is the counterpart of the marginal value product derived from production function

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[8]Even the problem of water shortage can be solved with well irrigation. Preliminary results of an INCORA study in the area indicate that there is sufficient ground water to irrigate much of the zone. Cost studies, however, are still in process.

Table 18. Programmed Annual Rate of Return per Peso to Owned Capital

Resource Level	Maximizing Profit		Maximizing Rate of Return
	Rice Included	Rice Excluded	
VH-VH	.403	.490	.636
H-VH	.450	.510	.636
H-H	.450	.510	.636
M-H	.500	.530	.636
M-M	.500	.530	.580
L-M	.590	.590	.600
L-L	.557	.557	.560
VL-L	.567	.567	.574

Table 19. Programmed Annual Profits per Hectare

Resource Level	Maximizing Profit: Rice Included	Maximizing Profit: Rice Excluded	Maximizing Rate of Return
	pesos		
VH-VH	2,212	1,674	1,312
H-VH	1,906	1,633	1,312
H-H	1,906	1,633	1,312
M-H	1,678	1,570	1,312
M-M	1,678	1,564	1,413
L-M	1,343	1,343	1,322
L-L	1,316	1,316	1,315
VL-L	1,153	1,153	1,149

analysis. The shadow price indicates the amount by which profit would be increased with the addition of one unit of the resource which has been exhausted. In the basic program both machinery and capital[9] were completely used in all but the first resource combination level. Beginning at the high level of capital (4,600 pesos per hectare) the shadow prices were .104 pesos and .094 pesos for the first and second semester, respectively. That is, if one peso of additional capital were introduced into the program profit would be increased by these amounts. When capital was reduced to the low level (2,300 pesos per hectare) the shadow prices increased to .243 pesos and .302 pesos for the first and second semesters. In the program without the rice activity the shadow prices at the low level of capital input were .243 pesos and .276 pesos. The estimate for the second semester was lower here than in the basic program because sorghum was substituted for cotton rather than for rice, and cotton produced a lower profit per hectare than rice.

Comparison of the Linear Programming and Regression Results

Both the programming and regression results are based upon existing conditions. However, enterprise combinations currently on farms differ from those indicated to be most profitable by the programming solutions. In the study region nearly 90 percent of the farms are devoted solely to cotton, and this crop was grown in only one semester of the year. The program solutions, on the other hand, indicate that a

[9]Capital here refers to total cash cost of the crop, excluding costs associated with buildings.

combination of crops would maximize profit and that double-cropping would increase annual profits.

If one were to assume that all rice growers had no capital restrictions (at least within the range of the costs of the four crops) it would pay them to produce rice exclusively. However, the irrigation requirement allows this crop pattern to be applied only to a small portion of the land in the zone. Farmers on non-irrigated land must look to crops other than rice as production alternatives. In the program without the rice growing activity cotton dominates the second semester when capital and machinery are not limiting, but it is not planted on 100 percent of the land due to the labor restriction. However, once constraints are placed on capital, cotton quickly declines in importance, and at the low levels it disappears.

Based on the MVPs from the production function analysis the indication is that resources other than labor should be taken out of cotton production and used for other crops. With the exception of machinery the MVPs of the inputs in sorghum and sesame have high positive values. A reasonable reaction to these indicators would be to shift these inputs out of cotton and to either diversify during semesters, or to introduce a rotation crop in the first semester if the farmer were opposed to abandoning cotton completely.

Alternative Objective Criteria and Resulting Crop Selection

In the final section of Chapter II, four income objectives were discussed. When these criteria were applied to the data from the study area the crops which best satisfied them varied among the four alternative objectives. The following discussion outlines the conditions

in the study area and the crops most consistent with these different income goals.

Maximize the Probability of Realizing a Selected Income Level

The minimum necessary income level chosen for the study area was 15,000 pesos per semester. This amount is one-half of the figure generally given as an acceptable income, and enough to support an average family for this short period of time. Table 20 gives the number of hectares required to earn 15,000 pesos with the indicated probability of attainment. The expected profits in Table 20 are taken from Table 34 in the appendix. These profit levels are the lowest that were considered acceptable for application in the risk model. The probabilities of realizing these profits were calculated from data given in Table 35 by summing the probability of occurrence of each yield-price combination that produced an acceptable profit. If production in the first semester were sufficient to yield the 30,000 pesos which satisfies the annual minimum necessary income, then this conservative approach could be abandoned and some income maximizing scheme adopted. However, if the first semester crop is poor, the program used in the first semester would be used again.

The analysis indicates that rice, sesame, and sorghum would each require about 20 hectares to provide 15,000 pesos per semester with close to an 80 percent chance of success. Sorghum offers the highest probability of attaining the necessary income level. However, if the farm is used for rice production, the probability of success for rice is perhaps not sufficiently lower (.78 for rice versus .83 for sorghum) to warrant 20 hectares of sorghum on an otherwise homogeneous crop area.

Table 20. Area Needed to Earn 15,000 Pesos in One Semester and the Probability of Success[a]

Crop	Area	Probability	E [Π] per Hectare at Given Probability Level
	Hectares		Pesos
Cotton	31	.71	487
Rice	18	.78	1,071
Sesame	20	.79	764
Sorghum	20	.83	765

[a]See appendix for probabilities.

With the required area producing the relatively low risk crop to guarantee, as much as possible, the minimum necessary income, the remainder of the farm could be used for the crops which maximize profit or rate of return.

Minimizing Expected Losses[10]

There was a wide range in the expected value of the losses among the crops in the study, with the highest losses in the high cost crops. In Table 21 the values of the loss components and the magnitude of the total cost of the loss (T_ℓ) are given.

The value for R (i.e., .10) which was chosen was based on the approximate rate of return on short term government development bonds. It was believed that this alternative could be considered risk-free, and the short term (6 months) of investment minimizes the loss due to

[10]Symbols are defined in Chapter II, pg. 31-33.

Table 21. Total Cost of Loss[a]

Crop	R	K	Π_ℓ	C	I	T_ℓ
Cotton	.10	2,038	- 655	3,500	.10	-1,209
Rice	.10	2,764	-1,527	3,400	.10	-2,143
Sesame	.10	1,026	- 497	1,200	.10	- 720
Sorghum	.10	1,415	- 391	1,300	.10	- 622

[a] $T_\ell = RK - \Pi_\ell + (C)(I)$

where: R = risk-free rate of return
K = owned capital, pesos
Π_ℓ = negative profit, pesos
I = penalty interest, pesos
C = borrowed capital, pesos

inflation. Coincidentally, I also was given a value of .10. This amount represents the difference between the interest rate (14 percent) charged for the major portion of agricultural loans and the maximum legal rate (24 percent) that commercial banks are permitted to charge. Using the maximum difference will bias the choice of loss minimizing crops toward low capital consuming ones.

As seen in the T_{ℓ} column in Table 21 sorghum and sesame have the smallest expected total cost of loss. If a farmer were to adopt these crops he would greatly decrease the potential loss encountered in any one year.

Maximizing Rate of Return to Owned Capital[11]

The rate of return data for the four crops in the study area are summarized in Table 22. Sesame is the crop indicated for those farmers who wish to maximize return to their capital, and sorghum is the crop for which the rate is the second highest.

Maximize Profit

The final income objective to be considered is profit maximization. Rice is the crop which earns maximum profits, if irrigated land is available (Table 23). On non-irrigated land first semester sorghum and second semester cotton would be the profit maximizing combination.

A Further Note on the Results of the Linear Programs

For low levels of capital availability the programming solutions

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[11] Owned capital is the difference between total cost and the amount of credit available from FFA and cotton association credit sources.

Table 22. Return to Owned Capital for Cotton, Rice, Sesame, and Sorghum

Crop	Owned Capital	Expected Net Return	Rate of Return to Owned Capital
	--------- pesos	---------	
Cotton	2,038	957	.47
Rice	2,764	1,086	.40
Sesame	1,026	652	.64
Sorghum	1,415	728	.51

Table 23. Gross Income, Cost, and Expected Profits per Semester for Cotton, Rice, Sesame, and Sorghum

Crop	$E[N]$[a]	Cost	$E[\Pi]$
	pesos		
Cotton	6,495	5,538	957
Rice	7,250	6,164	1,086
Sesame	2,878	2,226	652
Sorghum	3,443	2,715	728

[a]Gross income = N.

indicate that profits and rate of return would be maximized with combinations of sesame and sorghum. In both of the preceding risk avoiding models sesame and sorghum again appeared. It is interesting to note, then, that for farmers with very limited capital resources, rice and cotton would be neither the income maximizing nor the risk minimizing crops. By adopting other crops (e.g., sesame or sorghum), these farmers would be able to secure themselves against loss with a rather high degree of confidence, and also maximize profits.

CHAPTER VI

SUPPLY AND DEMAND FOR CAPITAL AND CREDIT[1]

One important question facing the developing countries concerns financing modernization or commercialization in agriculture. In this chapter the supply of capital from institutional credit sources and the demand for capital for use on farms in the study zone are examined. Demand is considered both as a demand for capital to finance total production costs, and to finance the cost of the non-traditional cash inputs. Demand for total capital is derived from the linear programming solutions, and the demand for NCI capital is derived from the results of the regression analysis.

After considering the supply and demand relationships a brief discussion of the adequacy of capital supply in the study area is presented.

The Supply Function

The supply function for credit is a step function reflecting the amounts of credit which are available at various rates of interest. The three sources of credit included are the FFA, commercial banks, and crop associations. In the case of the commercial banks the assumption was made that the maximum interest rate is charged on all loans. The

[1]The discussion that follows is based on revenues and costs per hectare.

amount of credit per hectare which can be obtained from the FFA and the crop associations is limited. The maximum that can be borrowed from the FFA is established by law and varies among crops. The limits on loans from the crop associations are taken from estimates of the amount frequently borrowed by members. As this credit can be applied only to NCI the quantity required does have this approximate limit.

The Demand Functions

Demand functions were derived for total capital used in the production process, and for the non-traditional cash inputs. The first function is by crop and is based upon data taken from the linear programming solutions. The second function is also by crop, but only for cotton and rice, and is derived from the regression analysis. In both cases demand is considered to be a function of the MVP of the respective input. In order to scale the MVP to the equivalent of the interest rate, the quantity MVP-1 is used to derive the demand function. The total cost of capital is equal to 1+i; however, the net cost of capital is equal to the interest rate (i). The equilibrium point between supply and demand for capital is where MVP=1+i, or, in terms of interest rate alone, where MVP-1=i.

Demand Derived from the Programming Solutions

The MVP of an input can be approximated by using the shadow prices in the programming solution. The shadow prices given represent the addition to profit that would be gained by using an additional unit of capital, that is, one peso. The shadow prices were calculated using capital input coefficients and a profit function which includes interest

costs. To express the shadow prices, or marginal rates of return,[2] as the MVP of capital the following transformation was made.

Letting,

R = revenue

C = total production cost exclusive of interest (that is, all inputs expressed in terms of an aggregate capital input)

i = interest rate

SP = r = shadow price or net rate of return,

then,

$$\frac{R - C(1+i)}{C(1+i)} = SP = r. \tag{6-1}$$

Equation (6-1) expresses the rate of return to capital with interest costs included, as calculated in the linear programming solution. By simplifying and combining terms (Equations 6-2 through 6-4) AVP can be expressed in terms of the shadow price, or rate of return. This value for AVP does not have interest costs included.

$$\frac{R}{C(1+i)} - 1 = r \tag{6-2}$$

$$\frac{R}{C(1+i)} = r + 1 \tag{6-3}$$

$$\frac{R}{C} = AVP = (r+1)\ (1+i) = r(1+i) + i + 1 \tag{6-4}$$

In a linear production function which passes through the origin the MVP = AVP of an input.

Let $Y = bX$

thus, $AP = \frac{Y}{X} = b$

[2]In this case, shadow price may be considered as a net rate of return in that it represents the increase in profit--a net value per unit of input.

and, $MP = \frac{dy}{dx} = b$

$\therefore (AP)\ (P_y) = AVP = (MP)\ (P_y) = MVP.$

Therefore,

$$AVP = MVP = r(1+i) + i + 1.$$

The shadow prices and MVPs of capital for cotton, rice, sesame, and sorghum are summarized in Table 24.

The derived demand functions are discontinuous step functions. The discontinuities result from discrete quantities of capital being used in the linear program; it is for these specified levels that the shadow prices are given. The functions all demonstrate the expected relationship between MVP and quantity of capital; decreasing marginal productivity is indicated as larger amounts of the input are used.

Although the shadow prices for capital differ slightly between semesters, the MVP from only one of the semesters was chosen to derive the demand curve with respect to each crop. In no case, however, would the choice of one semester over the other affect the general outcome of the supply and demand analysis.

At the point where total capital requirement--total cost of production[3]--is reached, the MVP-1 is equal to the interest rate. At higher levels of capital, when it ceases to be a scarce resource, the MVP is not meaningful in a programming framework. The contribution of the input beyond this point is assumed to be zero.

Demand Derived from Regression Analysis

The demand for the non-traditional cash inputs was derived for

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[3]These costs were rounded-off from the costs calculated in the study.

Table 24. Shadow Prices and MVPs of Capital

	Including Rice				Excluding Rice			
	Semester 1		Semester 2		Semester 1		Semester 2	
Capital	r=SP	MVP-1	r=SP	MVP-1	r=SP	MVP-1	r=SP	MVP-1
-Pesos-	--------- Rate per Peso ---------				--------- Rate per Peso ---------			
6,200	0	.14	0	.14	0	.14	0	.14
4,600	.104	.26	.094	.25	0	.14	.055	.20
3,450	.104	.26	.094	.25	0	.14	.055	.20
2,300[a]	.243	.42	.302	.48	.243	.42	.260	.44
2,000[a]	.243	.42	.302	.48	.243	.42	.276	.45

[a]Only sorghum and sesame appear in the solution at these capital input levels.

cotton and rice using the MVPs from the production functions. These functions are continuous and negatively sloping. Both the demand function for cotton and that for rice are essentially linear in the relevant range of input quantity indicating that the MVP's are decreasing at a nearly constant rate.

A summary of the MVPs is given in Tables 25 and 26.

Relation Between Supply and Program Derived Demand for Capital

The demand and supply functions relate the MVP of capital to its supply prices, that is to the interest rate in relation to quantity. The quantity at which the MVP curve intersects the supply curve is the profit maximizing level of input use. However, in the present case both of these functions are step functions, and a unique equilibrium point may not be indicated. Yet, for each crop, with the exception of rice, the question regarding an equilibrium level of capital is answered.

For cotton, there is a level of capital for which it is clearly indicated that the price (i) is greater than the MVP. Using this simple, and perhaps somewhat naive, decision criterion borrowing should not take place beyond this level. In the case of both sesame and sorghum the MVP remains greater than the price of capital throughout the relevant range of capital use. Thus, although supply and demand analysis does not determine an equilibrium point, it solves the problem as to the level of capital use by showing that financing 100 percent of the production costs through borrowing is economically justifiable.

For rice the supply and demand analysis, as used with cotton, sesame, and sorghum, does not provide a clearcut answer concerning the use of borrowed capital. There is no overlap between the supply and

Table 25. MVP of Non-Traditional Cash Inputs for Cotton

Input Level	MVP-1
------------- Pesos	-------------
300	3.48
600	1.70
900	0.36
1,200	-0.65
1,500	-1.01
1,800	-1.04

Table 26. MVP of Non-Traditional Cash Inputs for Rice

Input Level	MVP-1
------------- Pesos	-------------
500	24.44
1,000	16.12
1,500	7.80
2,000	-0.52
2,500	-8.84

demand functions, and the equilibrium level for borrowed capital is indeterminate given the derived curves. From a practical viewpoint, however, the probability of having one's entire rice crop financed through loans is quite small. The portion of total costs falling within the indeterminate range in question would most likely come from owned capital. The amount represents only 20 percent of the total capital input into the rice crop.

Cotton

The financing of cotton production should probably not be done from borrowed funds exclusively. Given the sources of credit available to the cotton grower only 3,500 pesos should be borrowed under the existing institutional framework. The return to capital at a level greater than 3,500 pesos is less than the 24 percent interest charge on commercial bank loans (Fig. 2). Therefore, the difference between the 5,500 peso cost of production and this 3,500 pesos must come from owned capital. The sources of the 3,500 pesos are FEDEALGODON--1,000 pesos at 6 percent interest, and FFA--2,500 pesos at 14 percent interest.

Rice

Analysis of the capital supply and demand functions indicates that the farmer could profitably borrow at least 4,900 pesos (FEDEARROZ--1,500 pesos at 9 percent, and FFA--3,400 pesos at 14 percent). The discontinuity in the demand function from 4,900 to 6,200 pesos prevents one from determining the point in this 1,300 peso range at which borrowing from commercial banks at 24 percent interest would be profitable (Fig. 3). If the MVP falls below .24 before 6,200 pesos are invested, then some of the production costs would have to be met by using owned capital.

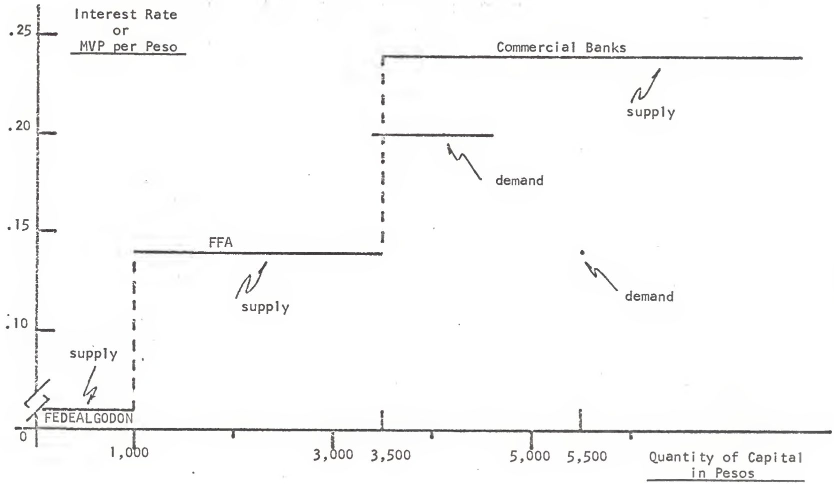

Figure 2.--Cotton: Supply and Demand for Capital per Hectare

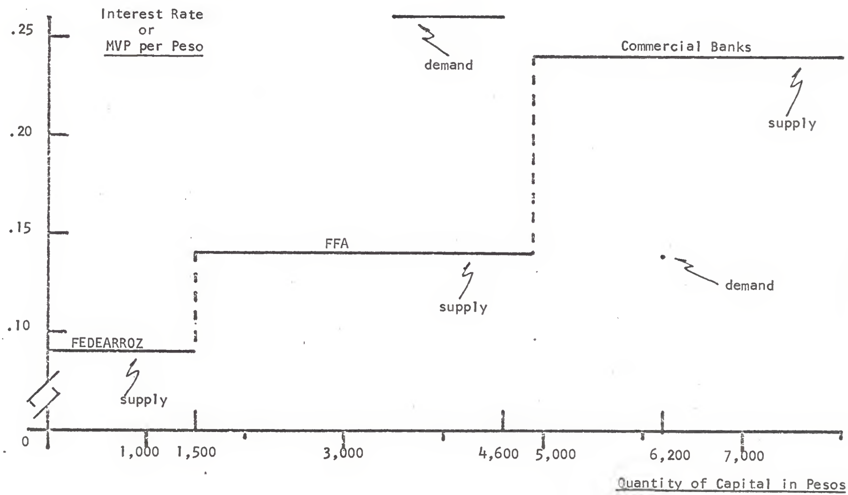

Figure 3.--Rice: Supply and Demand for Capital per Hectare

Sesame

If the sesame farmer could obtain a commercial bank loan then he could meet the total costs of production with borrowed capital (Fig. 4). The FFA provides more than one-half of the total costs at an interest rate of 14 percent. On the remainder of the capital, borrowed from the commercial banking system, MVP would exceed the 24 percent interest charge.

Sorghum

As in the case of sesame, credit could be used to completely finance the sorghum crop (Fig. 5). The 14 percent FFA rate and the 24 percent commercial bank rate of interest are below the .26 MVP of capital at 2,700 pesos, the total cost of sorghum production.

Relation of Supply and Regression Derived Demand for NCI

The step supply function is used again; however, the NCI demand functions are continuous and based upon the MVPs from regression analysis. Only cotton and rice are considered because NCI could not be incorporated into the production functions of sesame and sorghum.

Cotton

Approximately 1,000 pesos are available from the cotton federations at 6 percent interest. This credit is extended for the purchase of the non-traditional cash inputs. This horizontal supply function intersects the demand function at a quantity of approximately 950 pesos of NCI; thus, this single credit source provides adequate capital for the purchase of NCI (Fig. 6).

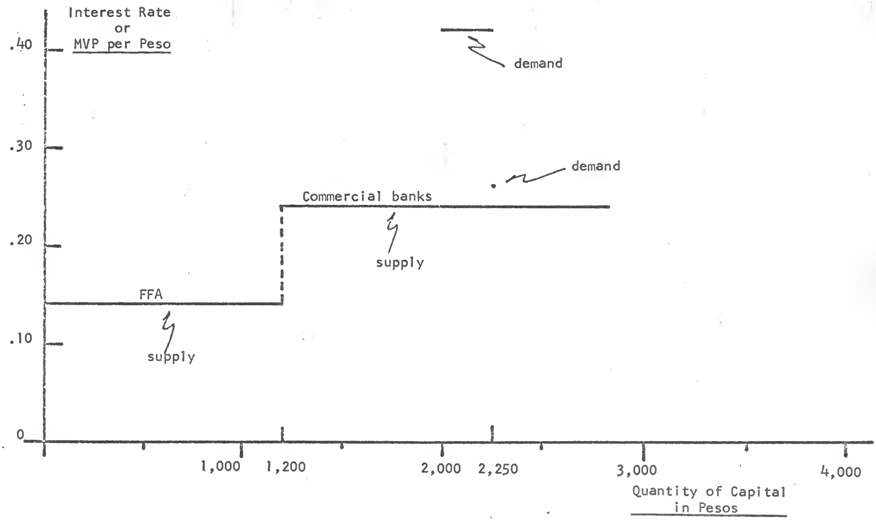

Figure 4.--Sesame: Supply and Demand for Capital per Hectare

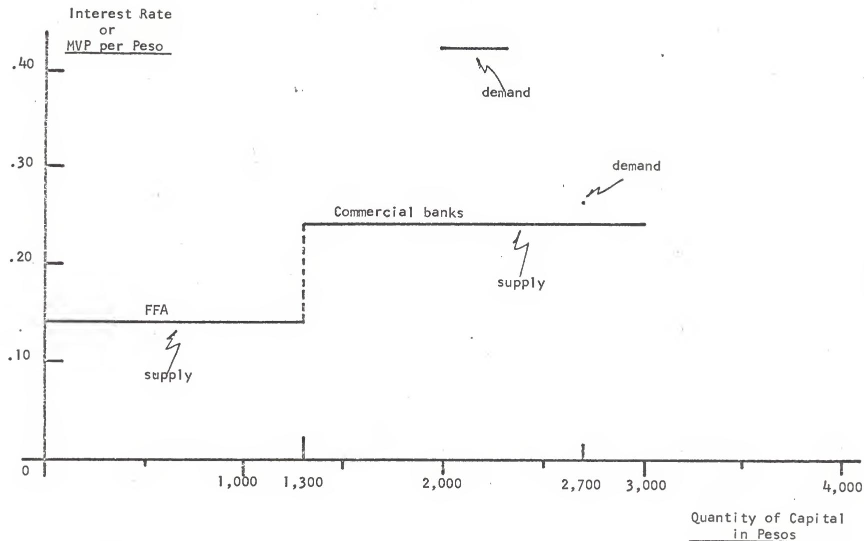

Figure 5.--Sorghum: Supply and Demand for Capital per Hectare

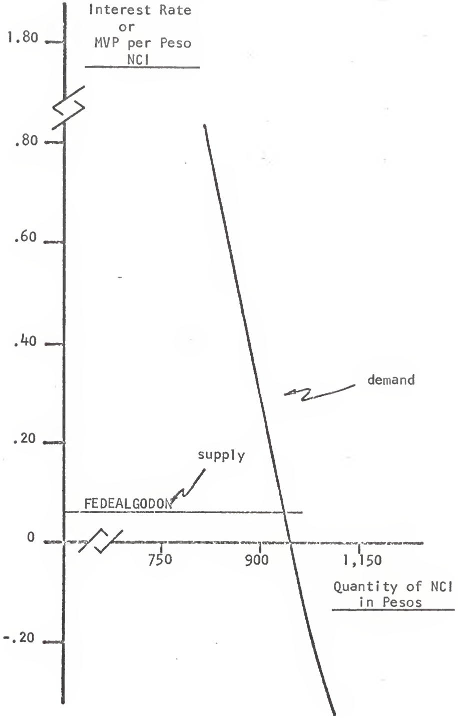

Figure 6.--Cotton: Supply and Demand for NCI per Hectare

Rice

Two sources of credit can be used to obtain the necessary funds for the NCI in rice. These sources are 1,500 pesos at 9 percent interest from FEDEARROZ, and 2,950 pesos at 14 percent interest from FFA (Fig. 7).

Conclusions Regarding Credit Supply and Demand

In light of the foregoing results it can be judged that the institutional credit system is adequate for present needs of farmers in the area. This conclusion is particularly true in the case of the non-traditional cash inputs for the two major crops in the region--cotton and rice. At least the major portion of total required capital is available for each crop at interest rates that are less than its MVP, and for sorghum and sesame total financing may be justified.

Three points should be kept in mind when considering these results. First, although 24 percent is the maximum legal interest rate on commercial bank loans, in many cases the rate actually charged may be less. Additional funds would be available if these rates fell below the MVP of capital at the given level of use. Second, the regulations of the FFA state that the credit available under this program is net of credit obtained from other sources. Thus, if strictly enforced, this rule would decrease the funds from FFA when additional sources of credit are used. However, from a practical standpoint the regulation may be ignored for the present, as it is not enforced in the study region. Finally, the above discussion assumes that any farmer can obtain commercial bank credit if he is willing to pay the 24 percent interest rate. This assumption is not completely

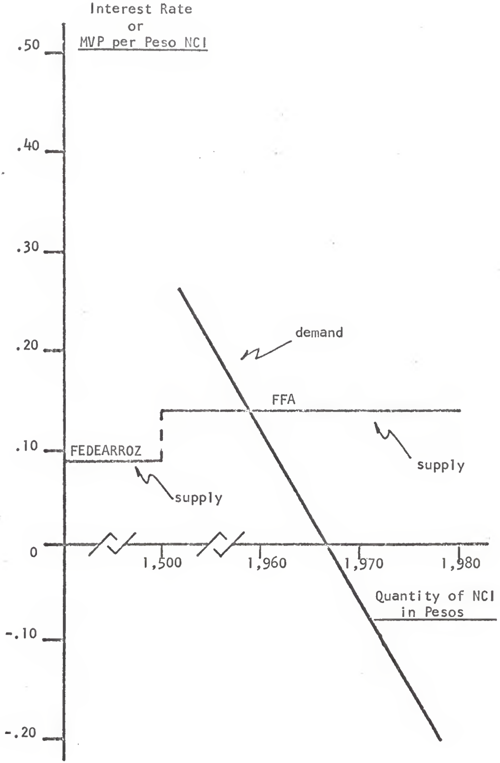

Figure 7.--Rice: Supply and Demand for NCI per Hectare

valid in that many farmers are denied loans by the banks. However, it is impossible to determine *a priori* what proportion of farmers have access to this credit source. For the individual farm, the credit standing of the farmer must be known in order to determine the amount that he can borrow and the interest rate that is charged by the commercial bank.

CHAPTER VII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The area chosen for this study lies in the cotton belt on the Northern Coastal Zone of Colombia. With the exception of small pockets of irrigated rice land, cotton dominates agricultural activity, and this region is the largest single cotton producing area in the country. Other crops in the region which were found in quantities to warrant inclusion in the study were rice (on irrigated land), sesame, and sorghum.

Objectives

The major objective of this study was to estimate the productivities of the agricultural inputs used in the study area. Based upon these productivities and additional information developed in this study, further analyses dealt with three matters:

1. The efficiency of the input mix and levels in the production of cotton, rice, sesame, and sorghum.
2. The allocation of resources among alternative crops.
3. The adequacy and allocation of credit.

Finally, recommendations were made with respect to the following items:

1. Credit policy.
2. Input levels for production of specified crops.

3. Crop combinations to achieve selected income goals: (a) maximizing income, (b) maximizing return to owned capital, (c) maximizing the probability of realizing selected income levels, and (d) minimizing losses.

An examination of the institutional supply of credit and capital inputs showed that the largest share of capital was obtained through joint programs of the commercial banks and the government, where the latter performed a supervisory role. Non-traditional cash inputs (herbicide, improved seed, fertilizer, and pesticide) were often obtained through government controlled outlets, and from privately organized crop associations in the cases of cotton and rice. Information on credit and capital supply was obtained from the agencies that supplied these factors.

Input-output data were obtained from a sample of farmers in the area by means of personal interviews. Multiple regression and linear programming techniques were employed to derive production functions, input productivities, and optimal input and output levels and combinations. In addition, probabilities of expected yields, prices, and profits were calculated and applied in simple risk-avoidance decision models. The analysis was concerned with determining the most efficient use of resources consistent with selected income goals of farmers.

Input Productivities

The marginal value productivities of tractor and machinery use (M), labor (L), and non-traditional cash inputs (NCI) were calculated from crop production functions. These values were as follows:[1]

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[1]Only the MVPs at the sample mean input levels are summarized

Crop	Input MVP: Machinery and tractor (M), hour	Labor (L), hour	Non-traditional capital (NCI), peso
	pesos		
Cotton	-37.7	26.3	-0.07
Rice	124.5	-261.6	-0.77
Sesame	-140.4	10.6	117.10
Sorghum	-100.8	41.3	Not Estimated

Given that machinery, labor, and NCI unit prices were 44.00, 3.75, and 1.08 pesos, respectively, it is evident that actual mean input levels in several of the input-crop cases differed substantially from estimated optimum levels. For each of the four crops there was at least one input over-used and one input under-used. This misuse of inputs resulted in profits that were below maximum levels.

The MVPs also indicate that the allocation of inputs among crops was far from optimum in the event that two or more of these crops were grown simultaneously. For example, shifting machinery time from sesame to rice, and NCI from rice to sesame would move the MVPs in the direction of equality, if these two crops were grown simultaneously.

Adequacy and Allocation of Credit

Supply and demand analysis indicated that there was generally a sufficient quantity of production credit available in the area. In many instances loans were available to cover the total amount of operating capital required for crop production. A major problem lies in the distribution and use of this credit. The excessive use of some inputs prevented portions of the loans from being spent on more profit-

here. The product prices per kilogram for cotton, rice, sesame, and sorghum were 3.70, 1.60, 4.60, and 1.20 pesos, respectively.

able inputs. This situation is well illustrated by the way in which funds were allocated among the non-traditional cash inputs. Although there was sufficient total credit available to purchase these inputs, an over-use of pesticides and an under-use of fertilizers were in evidence.

A second problem in credit distribution was the inaccessability of commercial bank loans for some farmers. Discrimination against operators of smaller farms and farmers with limited loan collateral prevented otherwise available funds from circulating.

In spite of some distribution problems it appears that the crop associations, commercial banks, and government supervised credit programs can provide adequate credit for most operators. It is not the purpose of the credit institutions, with the exception of commercial banks in some cases, to provide complete financing for farmers. Rather, the funds provided are viewed as supplements to the farmers' own capital, and often for the purpose of encouraging the use of specific inputs.

Conclusions

The conclusions are grouped under two headings, those dealing with cotton and those dealing with the other three crops.

Cotton

After examining the various aspects of cotton production it is obvious that there were many farmers for whom growing cotton could not be justified from an economic standpoint. Those farmers who have insufficient personal capital resources and limited access to credit are not in a position to continue with this high risk crop, especially

under the existing system of one crop of cotton per year. The analysis shows that these farmers could stabilize income and decrease the chances of a loss as well as increase profits if other crops were produced.

For those cotton growers who elect to continue producing this crop, the analysis indicates that changes in their farming practices would decrease costs, and increase yields and profits. Paramount among the possible changes are those with respect to fertilizer and pesticides. Indications, although as yet inconclusive, are that fertilizer is being under-used. The bases for levels of application were taken from ICA's recommendations which appear to come from inadequate experimentation.

The use of pesticides was such that costs were needlessly increased and yields were decreased. This result was probably due to an excessive number of applications, improper timing, use of broad spectrum pesticides, or low concentration of active ingredients.

The excessive use of machinery had a similar effect on costs, yields, and profits as described above in the case of pesticides. Decreased tractor time, presumably in the number of diskings, would have a positive effect on yields.

Finally, the problem of the harvest labor shortage is critical if this region is to continue or to increase its present emphasis on cotton. It appears that this shortage cannot be greatly reduced by a supply of temporary labor from other agricultural areas and from urban centers as has been done, with limited success, in the past. Mechanical pickers were introduced recently but, as yet, there is little information with regard to the economics of their use.

Rice, Sesame, and Sorghum

On irrigated land rice is an excellent crop for the region. Profit levels are higher and risk of failure is lower than for cotton. The current technology is quite efficient and approaches the optimum employment of inputs. The major limitation is the lack of irrigation water in most of the region. To date, there is little or no information regarding the economic aspects of deep well irrigation, nor indications as to what effect large scale ground water use would have on the region's water resources. A second factor which may limit the significant expansion of rice, if water were to become available, is its high capital requirements. Even with large sums of credit available from various sources, the individual farmer is frequently required to invest sizeable amounts of his own funds. For many farmers, sufficient capital is not available.

Sorghum and sesame are relatively new in the area. However, experience in this region and in other regions shows that both crops can supplement or be substituted for cotton. The principal advantages of these crops are their low capital requirements and low risk. Farmers with little capital can maximize profits with these two crops; at the same time, these crops provide a risk-averting system of production. If income objectives other than profit maximization are considered, sorghum and sesame appear to be good alternatives due to their low capital requirements, low risk, and high rate of return to capital.

Recommendations

Credit Policies

Three recommendations are made with regard to changes in credit policy. First, consideration should be given to the establishment of some form of loan insurance. This type of repayment guarantee would undoubtably lessen the reluctance on the part of commercial banks to extend credit to unknown borrowers, and to borrowers with little collateral. Second, the government should examine the possibility of creating a credit program for farm purchase. Presently, the government sponsored programs allocate funds for land rental, but not for farm purchase. A program of this type would decrease the insecurity of the present tenant farmers, and would be in accord with the current philosophy on land redistribution. Finally, crop associations similar to the existing ones for cotton and rice should be encouraged to establish offices and credit programs in the area. Such national associations already exist and, with the increasing importance of sesame and sorghum, are needed in the area.

Indicated Factor Levels

The following summary shows the factor levels which would maximize profit[2] for each crop:

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[2]Profit maximization for production with present practices and prices.

Crop	Input levels per hectare: Machinery in tractor hours	Labor in man hours	NCI in pesos
Cotton	4.8	301.4	970.0
Rice	8.6	42.6	1,963.4
Sesame	7.2	147.0	32.9
Sorghum	4.0	70.2	Not Estimated

These input levels were calculated from sample data. For sesame and sorghum the sample did not provide sufficient information for making estimates of total NCI use. For sesame only the seed component of NCI is used and for sorghum the NCI coefficient could not be estimated from available data. The tractor hours for cotton are for soil preparation operations only. The levels of inputs given above would maximize profit under the existing production techniques. There remains the question of determining the levels of the component inputs of the class, especially with respect to cotton. However, if the operations are well planned, these levels can in large part be determined. Certainly expenditures on herbicides, fertilizers, and seed can be closely estimated, and barring unusual conditions so can the costs of pest control.

Crop Combinations to Achieve Selected Income Goals

Not all farmers have identical income goals. The following summary presents four of the many alternative income objectives that any farmer might have, and indicates the enterprise combination which would enable him to best achieve each objective:[3]

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[3]Due to data restrictions crop possibilities considered here are limited to cotton, rice, sesame, and sorghum.

Income objective	Indicated crop or crop combination
Maximize profit	(a) Rice on irrigated land (b) Sorghum in first semester and cotton in second semester, if irrigation is not available
Maximize return to owned capital	Sesame in both semesters
Maximize probability of realizing a selected income (In this case 15,000 pesos per semester)	Sorghum for the semesters in which this is the objective
Minimizing losses	Sorghum

Suggestions for Further Investigation

On the government owned and operated experiment stations in the study zone much work could be done with cotton and other crops.

1. Experiments should be conducted with cotton to determine the relationship between quantity and timeliness in the use of pesticides. This would include:
   a. determining permissable levels of pest populations before spraying is done;
   b. working with biological control of pests;
   c. using spot or local spraying techniques;
   d. determining optimal hours of the day in which to spray;
   e. experimenting with products which are pest specific (i.e., those which cause minimum damage to the natural control agents).
2. Fertilizer response tests should be broadened to encompass a wider range of applied levels, especially in the upper limits of the amounts used (particularly for cotton and sorghum).

3. Mechanical cotton pickers should be brought into the operations on the experiment stations and the results carefully compared with those from hand picking. Possibly mechanical harvesters could be used to supplement hand labor to enable production to be increased in the zone, and also preserve employment for the permanent labor force in the region.
4. More varied and in depth experiments should be run with crops other than cotton. These crops include, but are not limited to, sorghum, sesame, soybeans, peanuts, and perhaps some annual fruit crops (e.g., melons and tomatoes). This work should emphasize the search for varieties best suited to the area and well-designed, complete experiments regarding all phases of production (e.g., machinery, seed, fertilizer, weed control, pesticides, and harvesting techniques). An important objective should be to find crops which would be most successful in rotation with cotton, which would enable cotton growers to utilize their fixed resources (e.g., land, machinery, and permanent labor) during the entire year.

APPENDIX

Table 27. Cotton: Estimated per Hectare Costs, Returns, and Input Use

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Total Revenue: Cotton	ton	1.90	3,600.00		6,840.00		
Operations and Variable Expenses							
Plowing	hr.	2.86	51.50	1	147.30	5.72	2.86
Disking	hr.	0.80	47.75	3	114.60	2.40	2.40
Planting	hr.	0.71	59.00	1	41.90	2.84	0.71
Seed	kg.	30.00	2.50	1	75.00		
Herbicide							
Treflan	lit.	3.00	113.47	1	340.41		
Fertilizer							
Urea (46% N)	kg.	200.00	2.00	1	400.00		
Application	hr.	0.56	52.40	1	29.34	2.24	0.56
Thinning	hr.	24.00	3.75	2	180.00	48.00	
Cultivation	hr.	1.00	47.75	2	95.50	2.00	2.00
Cultivation (hand)	hr.	26.67	3.75	2	200.00	53.34	
Hilling	hr.	.90	47.75	2	86.00	1.80	1.80
Insecticides							
Toxafeno DDT	gal.	1.00	54.05	4	216.16		
Methyl Parathion (48%)	gal.	0.40	73.45	6	176.28		
Serin 80	lb.	5.00	17.50	2	175.00		
Ekatin (25%)	lit.	1.00	42.00	1	42.00		
Application	ha.		30.00	10	300.00	0.50	
Technical Ass't.	ha.		100.00	1	100.00		

Table 27. Continued

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Harvesting							
Picking 1	12.5 kg.	91.20	7.00	1	638.40	91.20	
Picking 2	12.5 kg.	45.60	7.00	1	319.20	45.60	
Picking 3	kg.	190.00	1.00	1	190.00	50.64	
Packing, Transp.	ha.		489.00	1	489.00	2.00	0.50
Ginning	ton	1.90	180.00	1	342.00		
Plant Destruction							
Plowing	hr.	2.00	51.50	1	103.00	4.00	2.00
Disking	hr.	0.80	47.75	2	76.40	1.60	1.60
Administration	ha.		180.00	1	180.00		
Rent	ha.		650.00	1	650.00		
Social Security	ha.		90.00	1	90.00		
Total costs	ha.				5,790.29		
Return over cost	ha.				1,149.71		
Total hours	ha.					313.88	14.43

Table 28. Rice: Estimated per Hectare Costs, Returns, and Input Use

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Total Revenue: Paddy rice	ton	4.522	1,600.00		7,235.20		
Operations and Variable Expenses							
Plowing	hr.	2.86	51.50	1	147.30	5.72	2.86
Disking	hr.	0.80	47.75	3	114.60	2.40	2.40
Planting	hr.	0.63	59.00	1	37.17	2.52	0.63
Seed	kg.	135.00	4.00	1	607.50		
Fertilizer							
Urea (46% N)	kg.	280.00	2.00	1	560.00		
10-20-20	kg.	95.00	1.85	1	175.75		
Application	hr.	0.60	53.00	1	31.80	2.40	0.60
Fungicide							
Dithane M-45	lb.	4.00	11.45	1	45.80		
Cultivation	ha.		100.00	1	100.00	26.67	
Herbicide							
Stam-34	gal.	3.00	161.00	1	483.00		
Fedearroz 500	lit.	0.50	26.75	1	51.00		
Application	ha.		40.00	2	80.00		
Insecticide							
Toxafeno DDT	gal.	1.00	54.05	2	108.10		
Methyl Parathion	gal.	0.50	73.45	2	73.45		
Ekatin	lit.	0.50	40.00	1	20.00		
Application	ha.		30.00	4	120.00		
Bird Chasing	hr.	3.20	3.75	1	12.00	3.20	

Table 28. Continued

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Irrigation	ha.		420.00	1	420.00		
Technical Ass't.	ha.		100.00	1	100.00		
Harvesting							
Combining	ton	4.52	174.00	1	786.83		
Sacks	ea.	73.00	6.00	1	438.00		
Internal Transp.	ha.		59.00	1	59.00	4.00	1.00
External Transp.	sk.	73.00	2.00	1	146.00		
Rent	ha.		600.00	1	600.00		
Social Security	ha.		216.00	1	216.00		
Total cost					5,703.30		
Return over cost					1,531.90		
Total hours						46.91	7.49

Table 29. Sesame: Estimated per Hectare Costs, Returns, and Input Use

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Total Revenue: Sesame	kg.	650	4.60		2,990.00		
Operations and Variable Expenses							
Plowing	hr.	2.86	51.50	1	147.30	5.72	2.86
Disking	hr.	0.80	47.75	2	76.40	1.60	1.60
Planting	hr.	0.71	59.00	1	39.23	2.13	0.71
Seed	kg.	3.00	9.00	1	27.00		
Insecticide							
Methyl Parathion	gal.	0.30	73.45	1	22.33		
Application	ha.		30.00	1	30.75		
Thinning	ha.		70.00	1	70.00	18.66	
Cultivation (hand)	ha.		70.00	2	140.00	37.73	
Cultivation	hr.	1.00	47.75	1	47.75	1.00	1.00
Harvesting							
Cutting & piling	12.5 kg.	52.00	4.00	1	208.00	53.33	
Threshing	12.5 kg.	52.00	3.80	1	192.00	51.20	
Internal Transp.	hr.	0.50	59.00	1	29.50	2.00	0.50
External Transp. and Packing	100 kg.		27.25	1	163.50		
Technical Ass't.	ha.		60.00	1	60.00		

Table 29. Continued

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Administration	ha.		180.00	1	180.00		
Rent	ha.		535.00	1	535.00		
Social Security	ha.		226.00	1	226.00		
Total costs					2,194.76		
Return over costs					795.24		
Total hours						173.37	6.67

Table 30. Sorghum: Estimated per Hectare Costs, Returns, and Input Use

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Total Revenue: Sorghum	ton	2.90	1,200.00		3,480.00		
Operations and Variable Expenses							
Plowing	hr.	2.00	51.50	1	103.50	4.00	2.00
Disking	hr.	0.67	47.75	2	64.00	1.34	1.34
Planting	hr.	0.55	59.00	1	32.45	1.65	0.55
Seed	kg.	18.00	9.00	1	162.00		
Fertilizer							
Urea (46%)	kg.	100.00	2.00	1	200.00		
Application	hr.	0.55	59.00	1	32.45	1.65	0.55
Insecticide							
Toxafeno DDT	gal.	1.00	54.05	1	54.05		
Methyl Parathion	gal.	0.50	73.45	1	36.72		
Application	ha.		30.00	2	60.00		
Cultivation (hand)	ha.		70.00	1	70.00	18.67	
Cultivation	ha.	0.67	47.75	1	32.00	0.67	0.67
Bird Chasing	ha.		75.00	1	75.00	20.00	
Technical Ass't.	ha.		60.00	1	60.00		
Harvesting							
Combining	ton	2.90	175.00	1	507.50		
Internal Transp.	ha.		42.48	1	42.48	2.88	0.72
External Transp. and Packing	ha.		594.50	1	594.50		

Table 30. Continued

Item	Unit	Rate	Peso Price/Unit	Number	Total Value	Man Hours	Tractor Hours
Administration	ha.		180.00	1	180.00		
Rent	ha.		450.00	1	450.00		
Social Security	ha.		80.00	1	80.00		
Total costs					2,836.65		
Return over costs					643.35		
Total hours						50.86	5.63

Table 31. Estimated Total Costs of Production for Cotton, Rice, Sesame, and Sorghum, by Source, 1970

Crop	Source: Caja Agraria	ICA	FFA	Schwartz[a] (present study)
	pesos per hectare			
Cotton	5,700	5,976	5,700	5,538
Rice	6,285	6,504	6,500	6,164
Sesame	2,280	3,201	2,280	2,226
Sorghum	2,790	n.a.	2,790	2,715

[a]The Schwartz estimates are for the study zone; the other three sources are based on national cost calculations.

Table 32. Probabilities of the Occurrence of Good, Normal and Bad Yields[a] and Prices[a] for Cotton, Rice, Sesame and Sorghum in the Study Zone

Crop	$P[Y_g]$	$P[Y_n]$	$P[Y_b]$	$P[P_{Y_g}]$	$P[P_{Y_n}]$	$P[P_{Y_b}]$
Cotton	.200	.508	.292	.150	.755	.095
Rice	.240	.585	.175	.220	.694	.086
Sesame	.200	.652	.148	.120	.802	.078
Sorghum	.150	.759	.091	.120	.793	.087

[a]Yield (Y) and product price (P_y) are classified into three levels as follows:

n = normal,

g = good ($g \geq 1.1n$),

b = bad ($b \leq .9n$).

Table 33. Expected Yields and Prices in Good, Normal, and Bad Years for Cotton, Rice, Sesame, and Sorghum Based on Data Collected in the Present Study

Crop	$E[Y_g]$	$E[Y_n]$	$E[Y_b]$	$E[P_{y_g}]$	$E[P_{y_n}]$	$E[P_{y_b}]$
	------- kilograms		--------	---- pesos per kilogram ----		
Cotton	2,191	1,900	1,267	4.07	3.70	3.17
Rice	6,218	4,522	2,826	1.81	1.60	1.23
Sesame	793	650	352	5.12	4.60	2.97
Sorghum	3,509	2,900	1,789	1.35	1.20	0.90

Table 34. Estimated Profits[a] at Various Yield and Product Price Combinations

Pesos per Hectare										
Cotton						Rice				
		Yield						Yield		
		g	n	b				g	n	b
Price	g	3,378	2,195	-380		Price	g	5,088	2,018	-450
	n	2,568	1,492	-849			n	1,785	1,071	-1,342
	b	1,408	487	-1,520			b	1,496	-393	-2,791
Sesame						Sorghum				
		Yield						Yield		
		g	n	b				g	n	b
Price	g	1,830	1,099	-428		Price	g	2,014	1,193	-304
	n	1,421	764	-609			n	1,496	765	-568
	b	130	-294	-1,181			b	426	-119	-1,113

[a]Based on calculations from study data.

Table 35. Probabilities of the Occurrence of Combinations[a] of Good, Normal, and Bad Yields and Prices for Cotton, Rice, Sesame, and Sorghum

		Cotton					Rice		
		Yield					Yield		
		g	n	b			g	n	b
Price	g	.030	.076	.044	Price	g	.053	.129	.038
	n	.151	.384	.220		n	.167	.406	.121
	b	.019	.048	.028		b	.021	.050	.015

		Sesame					Sorghum		
		Yield					Yield		
		g	n	b			g	n	b
Price	g	.024	.078	.018	Price	g	.018	.091	.011
	n	.160	.523	.119		n	.119	.602	.072
	b	.016	.051	.012		b	.013	.066	.008

[a] P[Y] assumed independent of P $[P_y]$; g = good, n = normal, and b = bad.

Table 36. Linear Programming Matrix for Profit Maximization Solution, Rice Included

	Activities						
Resources	Cotton	Rice 1	Rice 2	Sesame 1	Sesame 2	Sorghum 1	Sorghum 2
Land 1[a]		1.000		1.000		1.000	
Land 2[a]	1.000		1.000		1.000		1.000
Capital 1[b]		6.164		2.226		2.715	
Capital 2[b]	5.538		6.124		2.226		2.645
Machinery 1[c]		8.430		8.750		5.400	
Machinery 2[c]	12.550		8.430		8.750		5.400
Profit[d]	957.000	1,086.000	1,126.000	652.000	·652.000	728.000	798.000

[a]In hectares.

[b]In 1,000 pesos.

[c]In hours.

[d]In pesos.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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